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(54) Title: METHOD OF INHIBITING NEUROTROPHIN-RECEPTOR BINDING			
(57) Abstract <p>The present invention relates to compositions which inhibit the binding of nerve growth factor to the p75^{NTR} common neurotrophin receptor and methods of use thereof. In one embodiment, the compound which inhibits binding of nerve growth factor to p75^{NTR} comprises, particularly when bound to nerve growth factor, at least two of the following: (1) a first electronegative atom or functional group positioned to interact with Lys³⁴ of nerve growth factor; (2) a second electronegative atom or functional group positioned to interact with Lys⁹⁵ of nerve growth factor; (3) a third electronegative atom or functional group positioned to interact with Lys⁸⁸ of nerve growth factor; (4) a fourth electronegative atom or functional group positioned to interact with Lys³² of nerve growth factor; and (5) a hydrophobic moiety which interacts with the hydrophobic region formed by Ile³¹, Phe¹⁰¹ and Phe⁸⁶ of nerve growth factor.</p>			

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METHOD OF INHIBITING NEUROTROPHIN-RECEPTOR BINDING

RELATED APPLICATION

This application is a continuation of U.S. Serial Number 09/310,883, filed May 17, 1999, the entire teachings of which are incorporated herein by reference.

5 BACKGROUND OF THE INVENTION

The neurotrophins are a family of structurally and functionally related proteins, including Nerve Growth Factor (NGF), Brain-Derived Neurotrophic Factor (BDNF), Neurotrophin-3 (NT-3), Neurotrophin-4/5 (NT-4/5) and Neurotrophin-6 (NT-6). These proteins promote the survival and differentiation of diverse neuronal populations in both the peripheral and central nervous systems (Hefti, 1986; Hefti and Weiner, 1986; Levi-Montalcini, 1987; Barde, 1989; Leibrock *et al.*, 1989; Maisonpierre *et al.*, 1990; Rosenthal *et al.*, 1990; Hohn *et al.*, 1990; Gotz *et al.*, 1994; Maness *et al.*, 1994) and are involved in the pathogenesis of diverse neurological disorders. Neurotrophins exert many of their biological effects through specific interactions with a class of transmembrane receptor tyrosine kinases (trkA, trkB and trkC) (Kaplan *et al.*, 1991; Klein *et al.*, 1991, 1992; Soppet *et al.*, 1991; Squinto *et al.*, 1991; Berkemeier *et al.*, 1991; Escandon *et al.*, 1993; Lamballe *et al.*, 1991). Specificity of neurotrophin action results from their selective interactions with the trk receptors. That is, trkA only binds NGF (Kaplan *et al.*, 1991; Klein *et al.*, 1991); trkB binds BDNF and NT-4/5 (Soppet *et al.*, 1991; Squinto *et al.*, 1991; Berkemeier *et al.*, 1991; Escandon *et al.*, 1993; Lamballe *et al.*, 1991; Klein *et al.*, 1992; Vale and Shooter, 1985; Barbacid, 1993); and trkC exclusively binds NT-3 (Lamballe *et al.*, 1991; Vale and Shooter, 1985). This is particularly evident when the trk receptors are coexpressed with the common neurotrophin receptor p75^{NTR}. (For review see Meakin and Shooter, 1992; Barbacid, 1993; Chao, 1994; Bradshaw *et al.*, 1994; Ibáñez, 1995).

The common neurotrophin receptor p75^{NTR} is a transmembrane glycoprotein structurally related to the tumor necrosis factor and CD-40 receptors (Meakin and Shooter, 1992; Rydén and Ibáñez, 1996). As all neurotrophins bind to p75^{NTR} with

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similar affinity (Rodriguez-Tébar *et al.*, 1990; Hallböök *et al.*, 1991; Rodriguez-Tébar *et al.*, 1992; Ibáñez, 1995), neurotrophin specificity is conventionally thought to be caused by the binding selectivity for trk receptors which are differentially expressed in different neuronal populations (Ibáñez, 1995). However, accumulated
5 experimental data on neurotrophin activity reveal important functional aspects of p75^{NTR} (Heldin *et al.*, 1989; Jing *et al.*, 1992; Herrmann, 1993; Barker and Shooter, 1994; Dobrowsky *et al.*, 1994; Matsumoto *et al.*, 1995; Marchetti *et al.*, 1996; Washiyama *et al.*, 1996). The common neurotrophin receptor enhances functions and increases binding specificity of trk receptors (Barker and Shooter, 1994;
10 Mahadeo *et al.*, 1994; Chao and Hempstead, 1995; Rydén and Ibáñez, 1996). In addition, p75^{NTR} possesses unique, trk-independent signaling properties which involve ceramide production through activation of the sphingomyelin cycle (Dobrowsky *et al.*, 1994), apoptosis (cell death) (Van der Zee *et al.*, 1996; Cassacia-Bonnefil *et al.*, 1996; Frade *et al.*, 1996), and activation of the transcription factor
15 NFκB (Carter *et al.*, 1996). Recently, p75^{NTR} has been demonstrated to participate in human melanoma progression (Herrmann *et al.*, 1993; Marchetti *et al.*, 1996). Furthermore, NGF and NT-3 increase the production of heparin by 70W melanoma cells, which is associated with their metastatic potential (Marchetti *et al.*, 1996). Although this effect has been shown to be mediated by the common neurotrophin
20 receptor, neither BDNF nor NT-4/5 appeared to be active.

Due to the implication of NGF/p75^{NTR} binding in various disease states, a need exists for pharmaceutical agents and methods of use thereof for interfering with the binding of NGF to the p75^{NTR} common neurotrophin receptor.

SUMMARY OF THE INVENTION

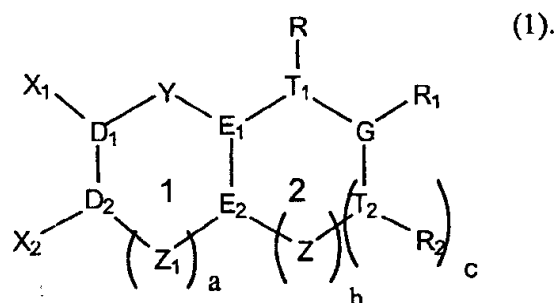
25 The present invention relates to the discovery of molecular structural features which contribute to the ability of a compound to inhibit the binding of NGF to the common neurotrophin receptor p75^{NTR}. Compounds which have these features are of use, for example, for inhibiting binding of NGF to p75^{NTR}. Such compounds can also be used to treat a patient having a condition which is mediated, at least in part,
30 by the binding of NGF to p75^{NTR}.

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In one embodiment, the present invention relates to compositions which inhibit the binding of nerve growth factor to the p75^{NTR} common neurotrophin receptor and methods of use thereof.

In one embodiment, the compound which inhibits binding of nerve growth factor to p75^{NTR} comprises at least two of the following: (1) a first electronegative atom or functional group positioned to interact with Lys³⁴ of nerve growth factor; (2) a second electronegative atom or functional group positioned to interact with Lys⁹⁵ of nerve growth factor; (3) a third electronegative atom or functional group positioned to interact with Lys⁸⁸ of nerve growth factor; (4) a fourth electronegative atom or functional group positioned to interact with Lys³² of nerve growth factor; and (5) a hydrophobic moiety which interacts with the hydrophobic region formed by amino acid residues of nerve growth factor, including Ile³¹, Phe¹⁰¹ and Phe⁸⁶. Such inhibitors, preferably, bind nerve growth factor via at least two of the foregoing interactions.

In one embodiment, compounds which inhibit binding of nerve growth factor to p75^{NTR} have Formula 1,



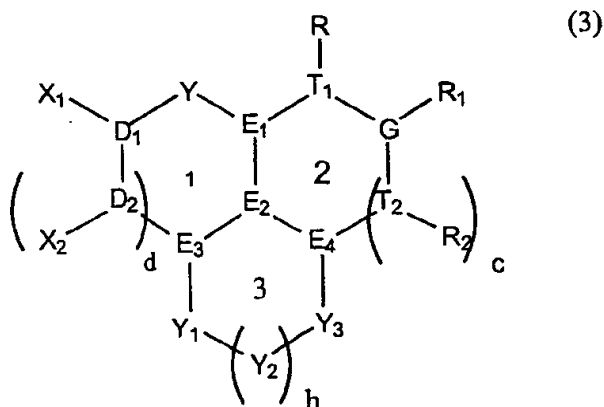
In Formula 1, D₁, D₂, E₁, E₂ and G are each, independently, an sp²-hybridized carbon or nitrogen atom. One of X₁ and X₂ is a hydrogen atom or absent, while the other is an electronegative atom or an electronegative functional group. R and R₂ are each, independently, an electronegative atom or an electronegative functional group, such as O, S, CH₂, or NR₃, where R₃ is H, alkyl, preferably C₁-C₆-alkyl, or aryl, such as phenyl. R, R₂ and one of X₁ and X₂ can also each be, independently, an electronegative atom or functional group, such as alkylcarbonyl; alkylthiocarbonyl;

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alkoxycarbonyl; aminocarbonyl; -OH; -CN; -CO₂H; -SO₃H; -SO₂H; -PO₃H₂; -NO₂; -ONO₂, -CNO, -SH, -CNS, -OSO₃H, -OC(O)(OH); halomethyl, dihalomethyl or trihalomethyl group or a fluorine, chlorine, bromine or iodine atom. Y is N, O, S, C, L or N-L, where L is H, alkyl, preferably C₁-C₆-alkyl, or an electronegative atom or functional group, such as, but not limited to, alkylcarbonyl; alkylthiocarbonyl; alkoxycarbonyl; aminocarbonyl; -OH; -CN; -CO₂H; -SO₃H; -SO₂H; -PO₃H₂; -NO₂; -ONO₂, -CNO, -SH, -CNS, -OSO₃H, -OC(O)(OH); halomethyl, dihalomethyl or trihalomethyl groups or a halogen atom, such as a fluorine, chlorine, bromine or iodine atom. Z and Z₁ are each, independently, O, S, CH, C(O), N, NH, N-alkyl, N-cycloalkyl and N-P, where P is a carbohydrate moiety, such as a monosaccharide group, for example, a fucosyl, glucosyl, galactosyl, mannosyl, fructosyl, gulosyl, idosyl, talosyl, allosyl, altrosyl, ribosyl, arabinosyl, xylosyl or lyxosyl group. T₁ and T₂ are each, independently, an sp²- or sp³-hybridized carbon or nitrogen atom. a, b, and c are each 0 or 1, provided that at least one of b and c is 1. R₁ is a monocyclic or polycyclic aryl or heteroaryl, monosaccharide or oligosaccharide, alkyl, cycloalkyl, arylalkyl, alkylamino or alkoxy group which is substituted with at least one substituent selected from the group consisting of electronegative atoms and electronegative functional groups.

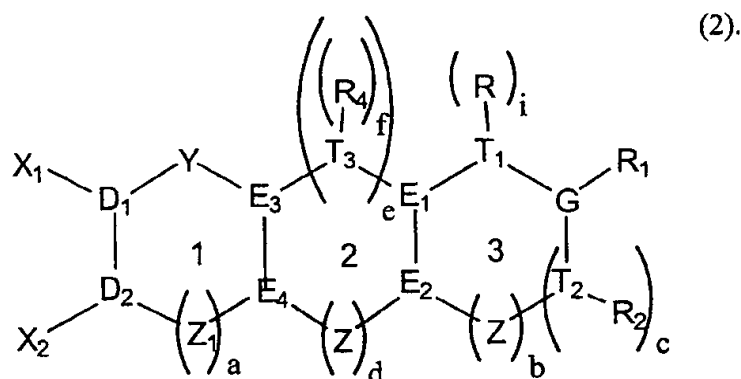
It will be appreciated that in this and the following structures, the lines connecting the variables can be single or double bonds. In addition, hydrogen atoms are added to the variables as necessary to complete the valence of the atom.

In another embodiment, the NGF/p75^{NTR} binding inhibitor has Formula 3



where D_1 , D_2 , X_1 , X_2 , Y , E_1 , E_2 , T_1 , T_2 , R , G , R_1 , R_2 , and c have the meanings given above for these variables in Formula 1. Y_1 , Y_2 , and Y_3 are independently selected from the identities given for Y in Formula 1. E_3 and E_4 are each, independently, an sp^2 -hybridized carbon or nitrogen atom, and d and h are, independently, 0 or 1.

- 5 In another embodiment, compounds which inhibit the binding of nerve growth factor to $p75^{NTR}$ have Formula 2,

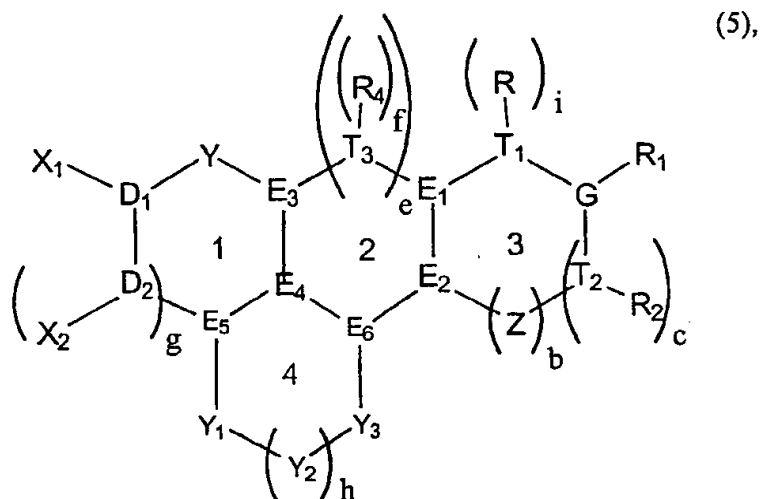


- In Formula 2, D_1 , D_2 , E_1 , E_2 , E_3 , E_4 and G are each, independently, an sp^2 -hybridized carbon or nitrogen atom. One of X_1 and X_2 is a hydrogen atom or absent, while the other is an electronegative atom or an electronegative functional group. R , R_2 and R_4 are each, independently, an electronegative atom or an electronegative functional group, such as O, S, CH_2 , or NR_3 , where R_3 is H, OH, alkyl, preferably C_1 - C_6 -alkyl, or aryl, such as phenyl. R , R_2 and one of X_1 and X_2 can also each be, independently, an electronegative atom or functional group, such as alkylcarbonyl; alkylthiocarbonyl; alkoxycarbonyl; aminocarbonyl; -OH; -CN; - CO_2H ; - SO_3H ; - SO_2H ; - PO_3H_2 ; - NO_2 ; - ONO_2 ; -CNO; -SH; -CNS; - OSO_3H ; - $OC(O)(OH)$; halomethyl, dihalomethyl or trihalomethyl group or a fluorine, chlorine, bromine or iodine atom. Y is N, O, S, C-L or N-L, where L is H, alkyl, preferably C_1 - C_6 -alkyl, or an electronegative atom or functional group, such as, but not limited to, alkylcarbonyl; alkylthiocarbonyl; alkoxycarbonyl; aminocarbonyl; -OH; -CN; - CO_2H ; - SO_3H ; - SO_2H ; - PO_3H_2 ; - NO_2 ; - ONO_2 ; -CNO; -SH; -CNS; - OSO_3H ; - $OC(O)(OH)$; halomethyl, dihalomethyl or trihalomethyl groups or a halogen atom, such as a fluorine, chlorine, bromine or iodine atom. Z and Z_1 are each,

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independently, O, S, CH, C(O), N, NH, N-alkyl, N-cycloalkyl and N-P, where P is a carbohydrate moiety, such as a monosaccharide group, for example, a fucosyl, glucosyl, galactosyl, mannosyl, fructosyl, gulosyl, idosyl, talosyl, allosyl, altrosyl, ribosyl, arabinosyl, xylosyl or lyxosyl group. T_1 , T_2 and T_3 are each, independently, an sp^2 - or sp^3 -hybridized carbon or nitrogen atom. When f is 0, T_3 can further have the meanings given for Z and Z_1 , above. a , b , c , d , e , f , g , h and i are each 0 or 1, provided that at least one of b and c is 1, at least one of d and e is 1 and at least one of f and i is 1. R_1 is a monocyclic or polycyclic aryl or heteroaryl, monosaccharide or oligosaccharide, alkyl, cycloalkyl, arylalkyl, alkylamine or alkoxy group which is substituted with at least one substituent selected from the group consisting of electronegative atoms and electronegative functional groups.

In another embodiment, a compound which inhibits the binding of NGF to p75^{NTR} has Formula 5,



wherein D_1 , D_2 , X_1 , X_2 , E_1 , E_2 , E_3 , T_1 , T_2 , T_3 , Z , G , R , R_1 , R_2 , R_4 , b , e , f , i , and c have the meanings given for these variables in Formula 2. Y_1 , Y_2 , and Y_3 are independently selected from the identities given for Y in Formula 2, and h is 0 or 1. E_5 and E_6 are each, independently, an sp^2 - hybridized carbon or nitrogen atom, and g is 0 or 1. Ring 4 can be further unsubstituted or substituted with one or more substituents, such as alkyl or aryl groups.

In another embodiment, the invention provides a pharmaceutical composition comprising at least one compound of the invention, or pharmaceutically acceptable salt thereof, in combination with a pharmaceutically acceptable carrier or excipient.

5 The invention also provides a method of inhibiting the binding of nerve growth factor to the p75^{NTR} receptor. The method comprises contacting cells which express the p75^{NTR} receptor with a nerve growth factor/p75^{NTR} binding inhibitor of the invention in an amount which is sufficient to inhibit binding of nerve growth factor to the p75^{NTR} receptor. The method can be practiced *in vivo* or *in vitro*.

10 In another embodiment, the invention relates to a method of treating a condition in a patient which is mediated by the binding of nerve growth factor to the p75^{NTR} receptor. The method comprises administering to the patient a therapeutically effective amount of a nerve growth factor/p75^{NTR} binding inhibitor of the invention. Preferably, the compound to be administered selectively inhibits the
15 binding of nerve growth factor to p75^{NTR} in cells which do not express the NGF receptor trkA.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 illustrates examples of suitable configurations for electronegative atoms in the NGF/p75^{NTR} binding inhibitors of the invention.

20 Fig. 2 illustrates examples of electronegative functional groups.

Fig. 3 sets forth a synthetic pathway for certain compounds of the invention; Pg = protecting group.

Fig. 4 sets forth a synthetic pathway for certain compounds of the invention.

Fig. 5 sets forth a synthetic pathway for certain compounds of the invention.

25 DETAILED DESCRIPTION OF THE INVENTION

Nerve growth factor (also referred to hereinafter as "NGF") is a neurotrophin implicated in the pathogenesis of Alzheimer's disease, epilepsy and pain (Ben and Represa, 1990; McKee *et al.*, 1991; Leven and Mendel, 1993; Woolf and Doubell, 1994; Rashid *et al.*, 1995; McMahon *et al.*, 1995). The binding of NGF to its

receptors is determined by distinct sequences within its primary amino acid structure. While several regions of NGF participate in the NGF/trkA interaction, mutation studies suggest that relatively few key residues, namely those located in the NGF amino and carboxyl termini, are required for high affinity binding.

5 NGF displays high and low affinity binding sites in sensory and sympathetic neurons and in pheochromocytoma PC12 cells (Sutter *et al.*, 1979; Landreth and Shooter, 1980; Schechter and Bothwell, 1981). The coexpression of the common neurotrophin p75^{NTR} receptor with trkA is required to form the high affinity binding site (Hempstead *et al.*, 1991; Barker and Shooter, 1994; Mahadeo *et al.*, 1994; Chao
10 and Hempstead, 1995). Several models of the trkA-p75^{NTR} interaction have been proposed to explain high affinity NGF binding (Bothwell, 1991; Chao, 1992b; Chao and Hempstead, 1995; Wolf *et al.*, 1995; Ross *et al.*, 1996; Ross *et al.*, 1997). These models differ with respect to direct (conformational model) or indirect (ligand-
presentation model) interaction of p75^{NTR} with trkA. Direct trkA-p75^{NTR} interaction
15 is consistent with much of the existing experimental data.

The hairpin loop at residues 29-35 of NGF is responsible for recognition by p75^{NTR} (Ibáñez *et al.*, 1992; Radziejewski *et al.*, 1992), while the amino and carboxyl termini are important binding determinants for recognition by the trkA receptor (Shih *et al.*, 1994; Moore and Shooter, 1975; Suter *et al.*, 1992; Burton *et al.*,
20 1992; Kahle *et al.*, 1992; Luo and Neet, 1992; Drinkwater *et al.*, 1993; Treanor *et al.*, 1995; Taylor *et al.*, 1991; Shamovsky *et al.*, 1998; Shamovsky *et al.*, 1999; WO 98/06048). Truncation of either the amino or carboxyl terminus of NGF produces less active NGF analogues; similarly most deletion or point mutations of the amino terminus also lead to NGF analogues with diminished activity (Shih *et al.*,
25 1994; Burton *et al.*, 1992, 1995; Kahle *et al.*, 1992; Drinkwater *et al.*, 1993; Treanor *et al.*, 1995; Taylor *et al.*, 1991). On the other hand, the NGFΔ2-8 (NGF with residues 2-8 removed) and NGFΔ3-9 deletion mutants are almost as active as wild type NGF (Drinkwater *et al.*, 1993). These NGF structure-activity relationships in combination with the considerable species variability (mouse, human, guinea pig
30 and snake) of the amino acid sequence of the NGF termini (McDonald *et al.*, 1991) are of potential value in understanding the NGF/trkA interaction.

NGF exerts its biological activity as a non-covalent dimer (Treanor *et al.*, 1995; Burton *et al.*, 1995; McDonald *et al.*, 1991; Ibáñez *et al.*, 1993; Bothwell and Shooter, 1977). Two 118 residue NGF monomers are dimerized by hydrophobic and van der Waals interactions between their three anti-parallel pairs of β -strands; consequently, the amino terminus of one NGF monomer and the carboxyl terminus of the other are spatially juxtaposed (McDonald *et al.*, 1991). Furthermore, although a dimer has 2 pairs of termini, only one pair of termini is required for trkA receptor recognition (Treanor *et al.*, 1995; Burton *et al.*, 1995).

The X-ray crystallographic 3-dimensional structure of a dimeric mouse NGF (mNGF) has been reported (McDonald *et al.*, 1991). However, within this structure, the amino terminus (residues 1-11) and the carboxyl terminus (residues 112-118) remain unresolved for both pairs of termini. High flexibility of the NGF termini makes it difficult to experimentally determine their bioactive conformations, particularly since transition metal ions commonly used in X-ray crystallography (McDonald *et al.*, 1991) have high affinity for His residues (Gregory *et al.*, 1993) which are present in the NGF amino terminus (Bradshaw *et al.*, 1994). Indeed, conformational alterations in the receptor binding domains of NGF caused by Zn^{2+} cations leading to its inactivation have been described recently (Ross *et al.*, 1997). Since the amino and carboxyl termini are crucial for NGF bioactivity as mediated via trkA and because of the significance of NGF in multiple neurologic disease processes, the determination of the biologically active conformation of these termini is an important and challenging problem for computational chemistry.

The present invention relates to the discovery of molecular structural features which contribute to the ability of a compound to inhibit the binding of NGF to the common neurotrophin receptor $p75^{NTR}$. Compounds which have these features are of use, for example, for inhibiting binding of NGF to $p75^{NTR}$. Such compounds can also be used to treat a patient having a condition which is mediated, at least in part, by the binding of NGF to $p75^{NTR}$.

Certain compounds which inhibit the binding of NGF to $p75^{NTR}$ are disclosed in copending U.S. patent application, serial no. 09/292,450, incorporated herein by reference in its entirety.

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In one embodiment, the present invention provides compounds which inhibit the binding of nerve growth factor (NGF) to the p75^{NTR} receptor. The compounds have at least two of the following characteristics: (1) a first electronegative atom or functional group positioned to interact with Lys³⁴ of NGF; (2) a second
5 electronegative atom or functional group positioned to interact with Lys⁹⁵ of NGF; (3) a third electronegative atom positioned to interact with Lys⁸⁸ of NGF; (4) a fourth electronegative atom or functional group positioned to interact with Lys³² of NGF; and (5) a hydrophobic moiety which interacts with the hydrophobic region formed by Ile³¹, Phe¹⁰¹ and Phe⁸⁶ of NGF. A compound having two or more of these
10 structural attributes is referred to herein as an "NGF/p75^{NTR} binding inhibitor". Preferably, the NGF/p75^{NTR} binding inhibitor has at least three of the foregoing attributes when bound to NGF, more preferably at least four such attributes. Most preferably, the NGF/p75^{NTR} binding inhibitor has each of the five foregoing attributes. Typically, an NGF/p75^{NTR} binding inhibitor of the invention interacts
15 with NGF via at least two of the foregoing interactions when bound to NGF.

The term "electronegative atom", as used herein, refers to an atom which carries a partial or full negative charge in a particular compound under physiological conditions. The electronegative atom can be, for example, an oxygen atom, a nitrogen atom, a sulfur atom or a halogen atom, such as a fluorine, chlorine, bromine
20 or iodine atom. Preferably the electronegative atom is an oxygen atom. The term "electronegative functional group", as used herein, refers to a functional group which includes at least one electronegative atom. Electronegative groups include acid functional groups and other polar functional groups. For example, suitable electronegative functional groups include, but are not limited to, carbonyl,
25 thiocarbonyl, ester, imino, amido, carboxylic acid, sulfonic acid, sulfinic acid, sulfamic acid, phosphonic acid, boronic acid, sulfate ester, hydroxyl, mercapto, cyano, cyanate, thiocyanate, isocyanate, isothiocyanate, carbonate, nitrate and nitro groups. It is to be understood that, unless otherwise indicated, reference herein to an acidic functional group also encompasses salts of that functional group in
30 combination with a suitable cation.

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An electronegative atom of the NGF/p75^{NTR} binding inhibitor bears a full or partial negative charge under physiological conditions and can, therefore, interact electrostatically with the positively charged side chain of an NGF lysine residue. This will be an interaction, such as, for example, a hydrogen bond, an ion/ion
5 interaction, an ion/dipole interaction or a dipole/dipole interaction. The hydrophobic region or moiety of the NGF/p75^{NTR} binding inhibitor can interact with a hydrophobic region of NGF via a hydrophobic interaction. Without being bound by theory, it is believed that compounds having the disclosed structural features can interact with NGF in such a way as to interfere with, and thereby inhibit, the binding
10 of NGF to p75^{NTR}.

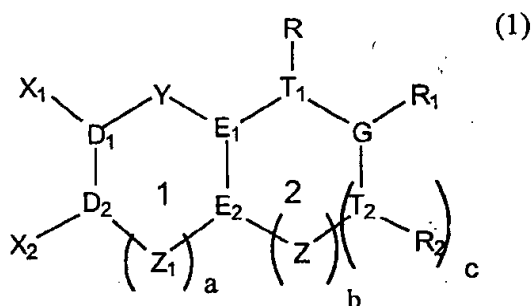
The ability of a compound to interact with the amino acid residues of NGF specified above can be determined using a structural model of NGF obtained using a energy-minimization algorithm, as described in published PCT application WO 98/06048, incorporated herein by reference in its entirety. For example, a
15 molecule will interact with the specified residues of NGF, as discussed above, if it has at least 3 electronegative atoms (A, B and C) such that at least one of the following two conditions is satisfied: (i) atoms A and B are separated by 5-7 covalent bonds, B and C are separated by 6-8 covalent bonds, and A and C are separated by 10-14 covalent bonds and (ii) distance between A and B is between 4.5
20 and 7.5 angstroms, and distance between B and C is between 4.5 and 7.5 angstroms. See Figure 1. The number of covalent bonds separating atoms can be determined from the structural formula of a molecule. Distance between atoms can be determined experimentally (e.g., by X-ray crystallography or NMR spectroscopy) or evaluated theoretically using any molecular builder (e.g., SYBYL from Tripos Inc.
25 (St. Louis, MO, USA) or QUANTA from Molecular Simulations Inc.(San Diego, CA, USA) as well as any molecular modeling technique (e.g., AMBER from Oxford Molecular Group Inc. /University of California, San Francisco or CHARMM from Molecular Simulations Inc.) or quantum chemical technique (e.g., MNDO from Oxford Molecular Group Inc. (Campbell, CA, USA) /University of Zurich;
30 AMPAC from Semichem (Kansas City, MO, USA); CADPAC from Oxford Molecular Group Inc./Cambridge University; Gaussian-98 from Gaussian Inc. (Carnegie, PA, USA); or GAMESS from Iowa State University). Examples of

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suitable configurations of groups A, B and C are illustrated in Fig. 1, while a representative group of electronegative functional groups is shown in Fig. 2.

Preferred NGF/p75^{NTR} inhibitors of the invention comprise a molecular scaffold or framework, to which the electronegative atoms or functional groups are attached, either directly or via an intervening moiety. The scaffold can be, for example, a cyclic or polycyclic moiety, such as a monocyclic, bicyclic or tricyclic moiety, and can include one or more hydrocarbyl or heterocyclic rings. Preferably, the scaffold includes two or more fused, planar, five- or six-membered rings. The molecular scaffold presents the attached electronegative atoms, electronegative functional groups or a combination thereof, in the proper configuration or orientation for interaction with the appropriate residues of NGF. In addition, the molecular scaffold, such as polycyclic system, or a portion thereof, can serve as the hydrophobic group which interacts with hydrophobic residues of NGF, as described above.

In one embodiment, the NGF/p75^{NTR} inhibitor is of general Formula 1,



In Formula 1, D₁, D₂, E₁, E₂ and G are each, independently, an sp²-hybridized carbon or nitrogen atom. One of X₁ and X₂ is a hydrogen atom or absent, while the other is an electronegative atom or an electronegative functional group. R and R₂ are each, independently, an electronegative atom or an electronegative functional group, such as O, S, CH₂, or NR₃, where R₃ is H, alkyl, preferably C₁-C₆-alkyl, or aryl, such as phenyl. R, R₂ and one of X₁ and X₂ can also each be, independently, an electronegative atom or functional group, such as alkylcarbonyl; alkylthiocarbonyl; alkoxy carbonyl; aminocarbonyl; -OH; -CN; -CO₂H; -SO₃H; -SO₂H; -PO₃H₂; -NO₂;

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-ONO₂, -CNO, -SH, -CNS, -OSO₃H, -OC(O)(OH); halomethyl, dihalomethyl or trihalomethyl group or a fluorine, chlorine, bromine or iodine atom. Y is N, O, S, C-L or N-L, where L is H, alkyl, preferably C₁-C₆-alkyl, or an electronegative atom or functional group, such as, but not limited to, alkylcarbonyl; alkylthiocarbonyl; 5 alkoxy carbonyl; aminocarbonyl; -OH; -CN; -CO₂H; -SO₃H; -SO₂H; -PO₃H₂; -NO₂; -ONO₂, -CNO, -SH, -CNS, -OSO₃H, -OC(O)(OH); halomethyl, dihalomethyl or trihalomethyl groups or a halogen atom, such as a fluorine, chlorine, bromine or iodine atom. Z and Z₁ are each, independently, O, S, CH, C(O), N, NH, N-alkyl, N-cycloalkyl and N-P, where P is a carbohydrate moiety, such as a monosaccharide 10 group, for example, a fucosyl, glucosyl, galactosyl, mannosyl, fructosyl, gulosyl, idosyl, talosyl, allosyl, altrosyl, ribosyl, arabinosyl, xylosyl or lyxosyl group. T₁ and T₂ are each, independently, an sp²- or sp³-hybridized carbon or nitrogen atom. a, b and c are each 0 or 1, provided that at least one of b and c is 1.

R₁ is a monocyclic or polycyclic aryl or heteroaryl, mono- or 15 oligosaccharide, alkyl, cycloalkyl, arylalkyl, alkylamino or alkoxy group which is substituted with at least one substituent selected from the group consisting of electronegative atoms and electronegative functional groups. Preferred monosaccharide groups include fucosyl, glucosyl, galactosyl, mannosyl, fructosyl, gulosyl, idosyl, talosyl, allosyl, altrosyl, ribosyl, arabinosyl, xylosyl and lyxosyl 20 groups. The electronegative substituent can be bonded to the aryl or heteroaryl ring system, alkyl, cycloalkyl, or oligo- or monosaccharide group either directly or indirectly via a bridging group, for example, an alkylene group such as a C₁-C₄-alkylene group or an oxaalkylene group. Suitable directly bonded and alkylene bridged electronegative atoms and functional groups include, but are not limited to, 25 alkylcarbonyl; alkylthiocarbonyl; alkoxy carbonyl; aminocarbonyl; -OH; -CN; -CO₂H; -SO₃H; -SO₂H; -PO₃H₂; -NO₂; -ONO₂, -CNO, -SH, -CNS; -OSO₃H; -OC(O)(OH); carboxyalkyl, nitroalkyl, N,N-dialkylaminosulfonyl, aminocarbonyl, alkoxy carbonyl, alkoxy carbonylalkyl, cyanocarbonylalkyl, haloalkyl, such as fluoromethyl, difluoromethyl, trifluoromethyl, chloromethyl, dichloromethyl or 30 trichloromethyl; alkylamido or a halogen atom, such as a fluorine, chlorine, bromine or iodine atom. In one embodiment, R₁ is selected from the group consisting of groups including, but not limited to, -(CH₂)_aCOOH; -(CH₂)_aNO₂; -(CH₂)_aOH;

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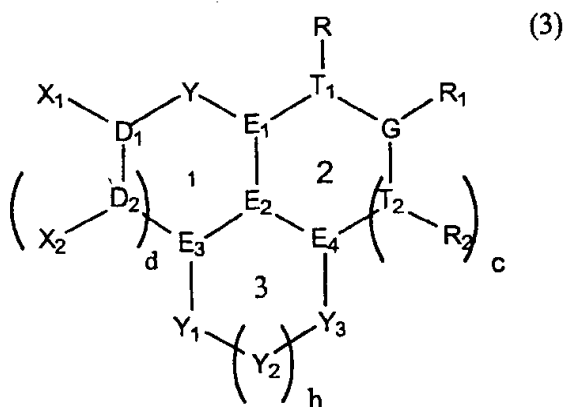
$-(CH_2)_aPO_3H_2$; $-(CH_2)_aSO_3H$; $-(CH_2)_aSO_2H$; $-R_4(CH_2)_aCOOH$; $-R_4(CH_2)_aNO_2$;
 $-R_4(CH_2)_aPO_3H_2$; $-R_4(CH_2)_aSO_2H$; $-R_4(CH_2)_aSO_3H$; and $-R_4(CH_2)_aOH$, where a is 1 to 12, preferably 1 to about 4, and R_4 is NH or O.

Rings 1 and 2 are each, independently, a five- or six-membered ring and,
 5 preferably, are both planar.

It is to be understood that compounds of Formula 1 and Formulas 2, 3 and 5,
 below, will further include double bonds between adjacent atoms as required to
 satisfy the valence of each atom. That is, double bonds are added to provide the
 following number of total bonds to each of the following types of atoms:
 10 four bonds; nitrogen: 3 bonds; oxygen: two bonds; and sulfur: two bonds.

The term "alkyl", as used herein, refers to a normal, branched or cyclic
 aliphatic hydrocarbyl group, which can be saturated or partially unsaturated.
 Preferred alkyl groups are normal, branched and cyclic C_1 - C_8 -alkyl and -alkenyl
 groups.

15 In another embodiment, the NGF/p75^{NTR} binding inhibitor of Formula 3



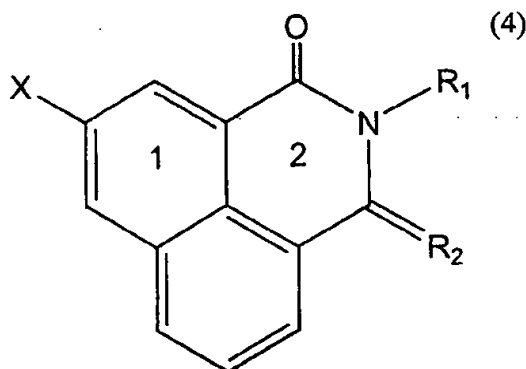
where D_1 , D_2 , X_1 , X_2 , Y , E_1 , E_2 , T_1 , T_2 , R , G , R_1 , R_2 , and c have the meanings given
 above for these variables in Formula 1. Y_1 , Y_2 , and Y_3 are independently selected
 20 from the identities given for Y in Formula 1. E_3 and E_4 are each, independently, an
 sp^2 -hybridized carbon or nitrogen atom, and d and h are each, independently, 0 or 1.

In one embodiment of the compounds of Formula 3, R_1 is a mono- or
 polycyclic aryl or heteroaryl, oligo- or monosaccharide group which is substituted
 with at least one electronegative atom or electronegative group. The mono- or
 25 polycyclic aryl or heteroaryl group is preferably substituted with an acid functional

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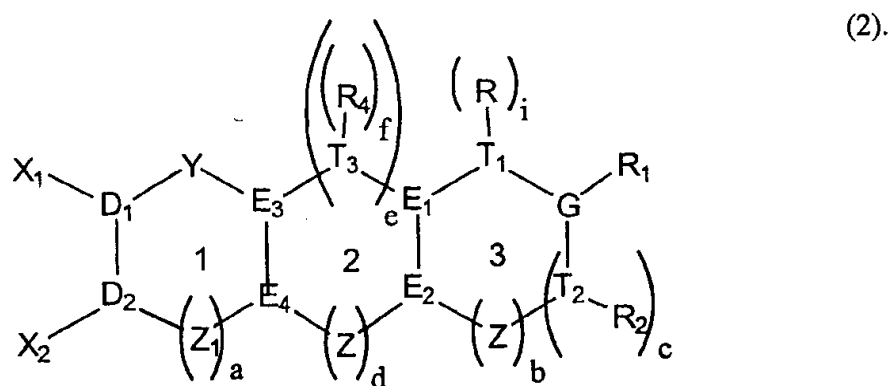
- group, such as alkyl-CO₂H; alkyl-SO₃H; alkyl-SO₂H; alkyl-PO₃H₂; alkyl-OSO₃H; where the alkyl group is preferably a C₁-C₄-alkyl group. In another embodiment, the electronegative atom or electronegative functional group is selected from the group consisting of alkylcarbonyl; alkylthiocarbonyl; alkoxycarbonyl; -CN; -NO₂; -ONO₂,
- 5 -CNO, -SH, -CNS, nitroalkyl, N,N-dialkylaminosulfonyl, aminocarbonyl, alkoxycarbonyl, alkoxycarbonylalkyl, cyanocarbonylalkyl, fluoromethyl, difluoromethyl, trifluoromethyl, chloromethyl, dichloromethyl, trichloromethyl, acetamido and halogen atoms. R₁ can also be an alkylamino, alkyl or alkoxy group which is substituted with at least one electronegative atom or functional group. For
- 10 example, in one embodiment, R₁ is selected from the group consisting of
 -(CH₂)_aNO₂; -(CH₂)_aOH; -(CH₂)_aPO₃H₂; -(CH₂)_aSO₃H; -(CH₂)_aSO₂H;
 -O(CH₂)_aCOOH; -O(CH₂)_aNO₂; -O(CH₂)_aPO₃H₂; -O(CH₂)_aSO₂H; -O(CH₂)_aSO₃H;
 -O(CH₂)_aOH; -NH(CH₂)_aCOOH; -NH(CH₂)_aNO₂; -NH(CH₂)_aPO₃H₂;
 -NH(CH₂)_aSO₂H; -and NH(CH₂)_aSO₃H; where a is 1 to 12, preferably 1 to about 4.
- 15 In another embodiment of the compounds of Formula 3, R₁ is a phenyl group which is substituted by p-toluenesulfonamido or hydroxyl; or R₁ is a -NH(CH₂)_aOH group, where a is 1 to about 4; a carboxyalkyl group, for example, a linear or branched carboxy-C₁-C₈-alkyl group; an alkoxycarbonyl group, such as a linear or branched C₁-C₈-alkoxycarbonyl group or an alkylcarbonate group, such as a linear or
- 20 branched C₁-C₈-alkylcarbonate group. In this embodiment, ring atom is an sp²-hybridized carbon atom, except for G, which is a nitrogen atom; R and R₂ are both O; and d, c and h are each 1.

Preferred compounds of Formula 3 are of the formula



where X and R₁ have the meanings given above for these variables in Formula 1, R₂ is O, CH₂ or NR₃, where R₃ is H, alkyl, preferably C₁-C₆-alkyl, or aryl, and rings 1 and 2 can, optionally, independently be further substituted. Suitable substituents include alkyl groups, preferably normal or branched C₁-C₆-alkyl groups and halogen atoms.

In another embodiment, the NGF/p75^{NTR} binding inhibitor is of Formula 2,



In Formula 2, D₁, D₂, E₁, E₂, E₃, E₄ and G are each, independently, an sp²-hybridized carbon or nitrogen atom. One of X₁ and X₂ is a hydrogen atom or absent, while the other is an electronegative atom or an electronegative functional group. R, R₂ and R₄ are each, independently, an electronegative atom or an electronegative functional group, such as O, S, CH₂, or NR₃, where R₃ is H, alkyl, preferably C₁-C₆-alkyl, or aryl, such as phenyl. R, R₂ and one of X₁ and X₂ can also each be, independently, an electronegative atom or functional group, such as alkylcarbonyl; alkylthiocarbonyl; alkoxy carbonyl; aminocarbonyl; -OH; -CN; -CO₂H; -SO₃H; -SO₂H; -PO₃H₂; -NO₂; -ONO₂; -CNO; -SH; -CNS; -OSO₃H; -OC(O)(OH); halomethyl, dihalomethyl or trihalomethyl group or a fluorine, chlorine, bromine or iodine atom. Y is N, O, S, C-L or N-L, where L is H, alkyl, preferably C₁-C₆-alkyl, or an electronegative atom or functional group, such as, but not limited to, alkylcarbonyl; alkylthiocarbonyl; alkoxy carbonyl; aminocarbonyl; -OH; -CN; -CO₂H; -SO₃H; -SO₂H; -PO₃H₂; -NO₂; -ONO₂; -CNO; -SH; -CNS; -OSO₃H; -OC(O)(OH); halomethyl, dihalomethyl or trihalomethyl groups or a halogen atom, such as a fluorine, chlorine, bromine or iodine atom. Z and Z₁ are each, independently, O, S, CH, C=O, N, NH, N-alkyl,

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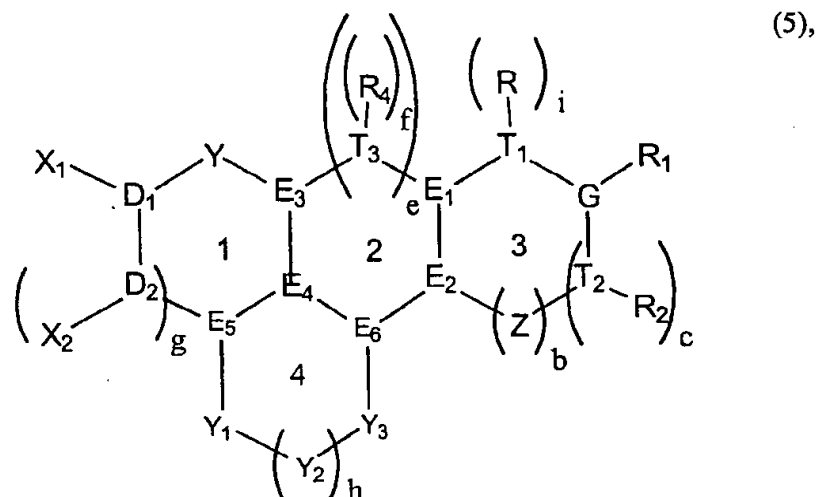
N-cycloalkyl and N-P, where P is a carbohydrate moiety, such as a monosaccharide group, for example, a fucosyl, glucosyl, galactosyl, mannosyl, fructosyl, gulosyl, idosyl, talosyl, allosyl, altrosyl, ribosyl, arabinosyl, xylosyl or lyxosyl group. T_1 , T_2 and T_3 are each, independently, an sp^2 - or sp^3 -hybridized carbon or nitrogen atom.

- 5 When f is 0, T_3 can further have the meanings given for Z and Z_1 , above. a , b , c , d , e , f and i are each 0 or 1, provided that at least one of b and c is 1; at least one of d and e is 1 and at least one of f and i is 1.

R_1 is a monocyclic or polycyclic aryl or heteroaryl, oligo- or monosaccharide, alkyl, cycloalkyl, arylalkyl alkylamino or alkoxy group which is substituted with at least one substituent selected from the group consisting of electronegative atoms and electronegative functional groups. Preferred monosaccharide groups include fucosyl, glucosyl, galactosyl, mannosyl, fructosyl, gulosyl, idosyl, talosyl, allosyl, altrosyl, ribosyl, arabinosyl, xylosyl and lyxosyl groups. The electronegative substituent can be bonded to the aryl or heteroaryl ring system, or monosaccharide group either directly or indirectly via a bridging group, for example, an alkylene group such as a C_1 - C_4 -alkylene group or an oxaalkylene group. Suitable directly bonded and alkylene bridged electronegative atoms and functional groups include, but are not limited to, alkylcarbonyl; alkylthiocarbonyl; alkoxy carbonyl; aminocarbonyl; -OH; -CN; -CO₂H; -SO₃H; -SO₂H; -PO₃H₂; -NO₂; 15 -ONO₂; -CNO; -SH; -CNS; -OSO₃H; -OC(O)(OH); carboxyalkyl, nitroalkyl, N,N-dialkylaminosulfonyl, aminocarbonyl, alkoxy carbonyl, alkoxy carbonylalkyl, cyanocarbonylalkyl, haloalkyl, such as fluoromethyl, difluoromethyl, trifluoromethyl, chloromethyl, dichloromethyl or trichloromethyl; alkylamido or a halogen atom, such as a fluorine, chlorine, bromine or iodine atom. In one embodiment, R_1 is selected from the group consisting of groups including, but not limited to, -(CH₂)_aCOOH; -(CH₂)_aNO₂; -(CH₂)_aOH; -(CH₂)_aPO₃H₂; -(CH₂)_aSO₃H; -(CH₂)_aSO₂H; -R₄(CH₂)_aCOOH; -R₄(CH₂)_aNO₂; -R₄(CH₂)_aPO₃H₂; -R₄(CH₂)_aSO₂H; -R₄(CH₂)_aSO₃H; and -R₄(CH₂)_aOH, where a is 1 to 12, preferably 1 to about 4, and R_4 is NH or O.

- 30 Rings 1, 2 and 3 are each, independently, a five- or six-membered ring and, preferably, are each planar.

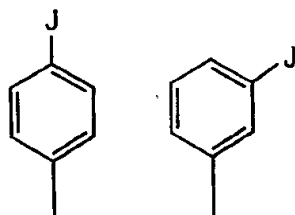
In another embodiment, the compound is of Formula 5,



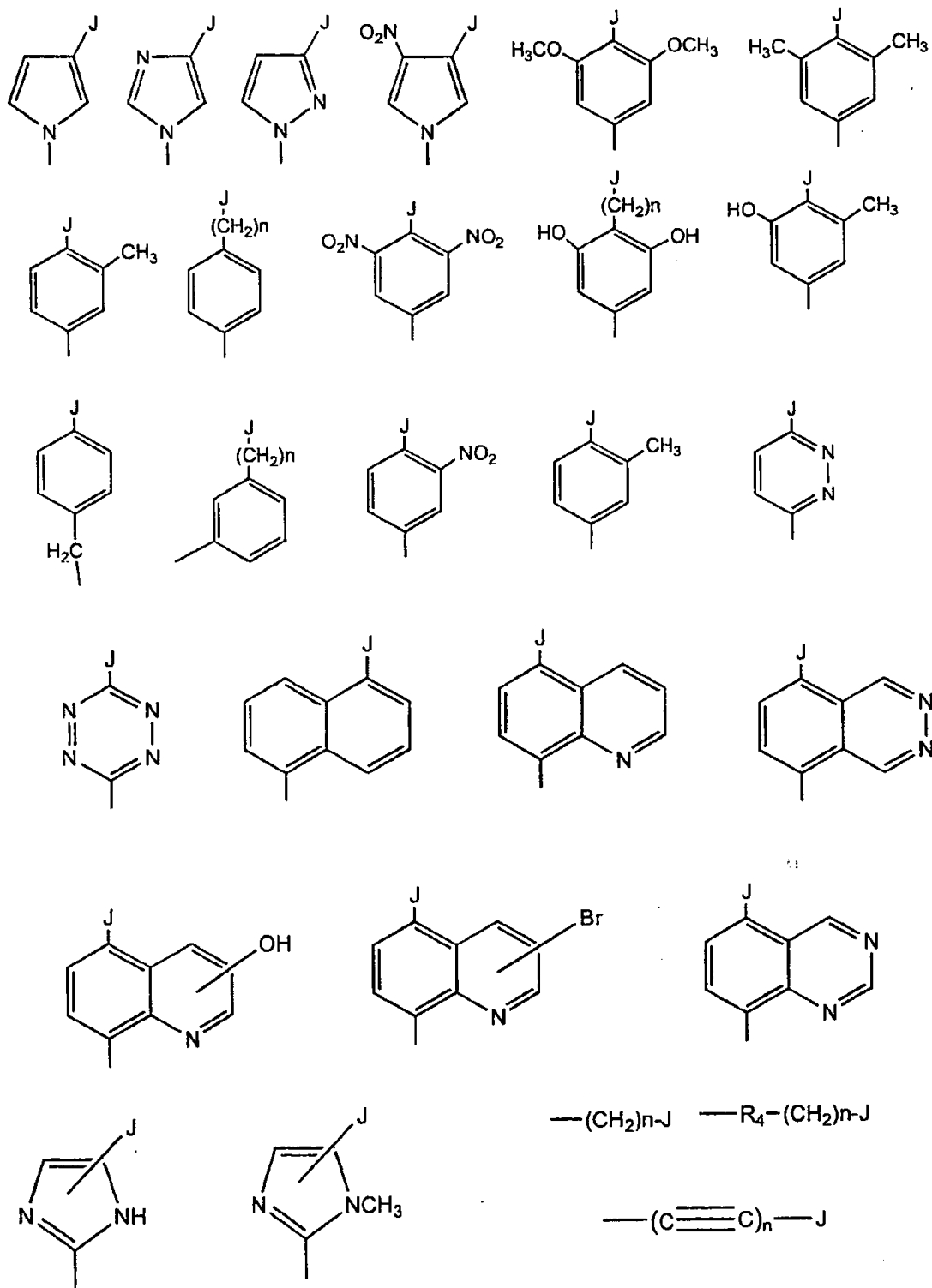
wherein D₁, D₂, X₁, X₂, E₁, E₂, E₃, T₁, T₂, T₃, Z, G, R, R₁, R₂, R₄, b, c, e, f and i have the meanings given for these variables in Formula 2. Y₁, Y₂, and Y₃ are

- 5 independently selected from the identities given for Y in Formula 2, and g and h are each, independently, 0 or 1. E₅ and E₆ are each, independently, an sp²- hybridized carbon or nitrogen atom, and g is 0 or 1. Ring 4 can be further unsubstituted or substituted with one or more substituents, such as alkyl or aryl groups.

- 10 In one embodiment of the compounds of Formulas 1, 2, 3 and 5, R₁ is selected from the group consisting of substituted phenylene, naphthylene, quinolylene and other substituted aromatic and heteroaromatic groups. R₁ can also be a substituted ethynyl or poly(ethynyl) group. Suitable identities for R₁ include, but are not limited to, the groups shown below.



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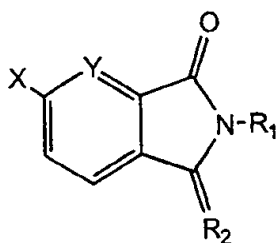


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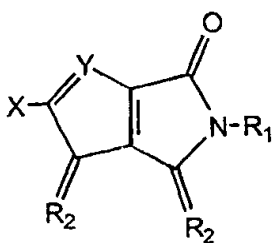
In each of these groups, J can be any of the electronegative atoms or groups described in the definition of R_1 in Formulas 1 and 2. Preferably, J is selected from the group consisting of -OH, -CN, -NO₂, -CO₂H, -SO₃H, -SO₂H, -F, -Cl, -Br, -I, -PO₃H₂, -CF₃, -SO₂N(CH₃)₂, -C(O)NH₂, -C(O)CH₃, -C(O)OCH₃, -C(O)CN, -CH₂F, -CH₂Cl, -CF₂H, -CCl₂H, -CCl₃ and -NHC(O)CH₃; R_4 is NH or O, and n is an integer from 0 to about 6.

Preferred compounds of Formula 1 are represented by Formulas 6-14, 16-18, 21-30 and 32-34, below. Preferred compounds of Formula 3 are represented by Formulas 15, 19, 20 and 31 below.

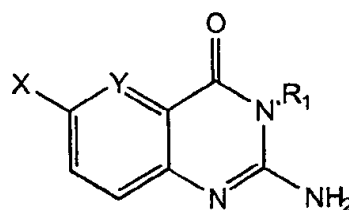
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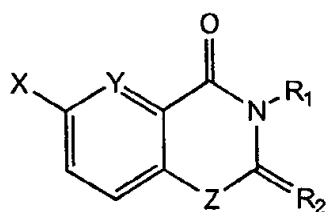
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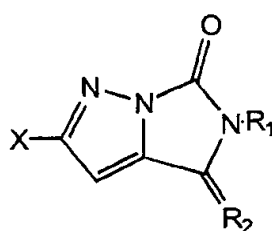
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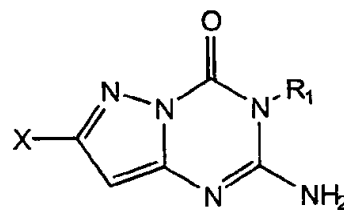
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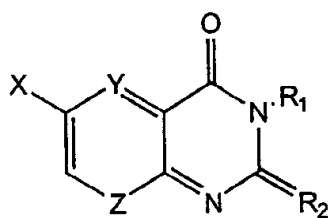
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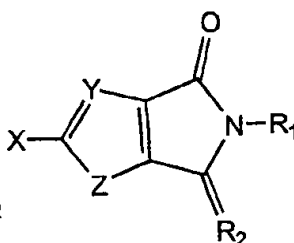
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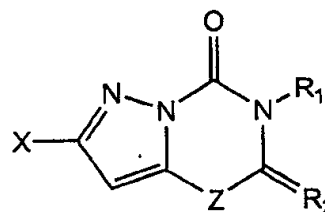
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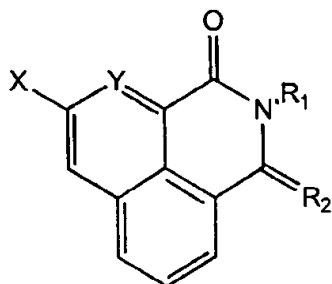
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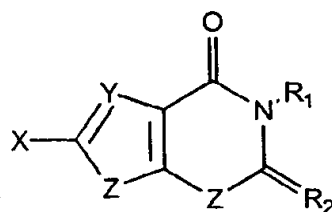
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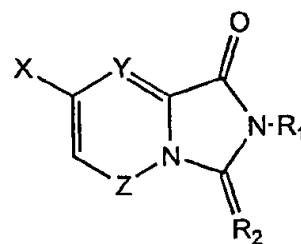
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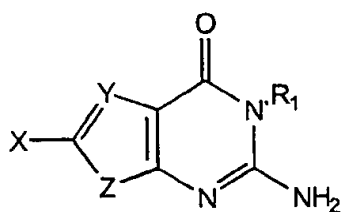
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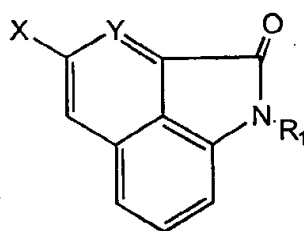
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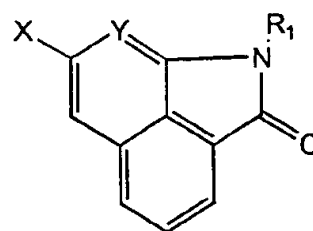
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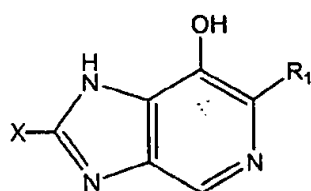


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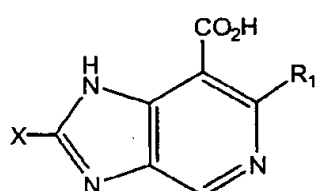


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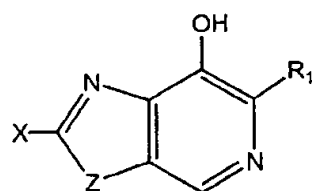
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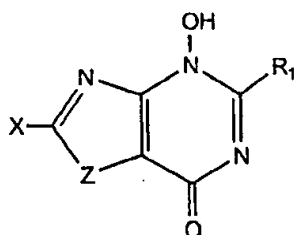
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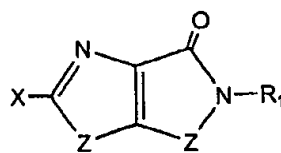
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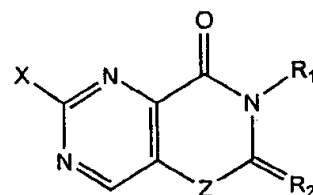
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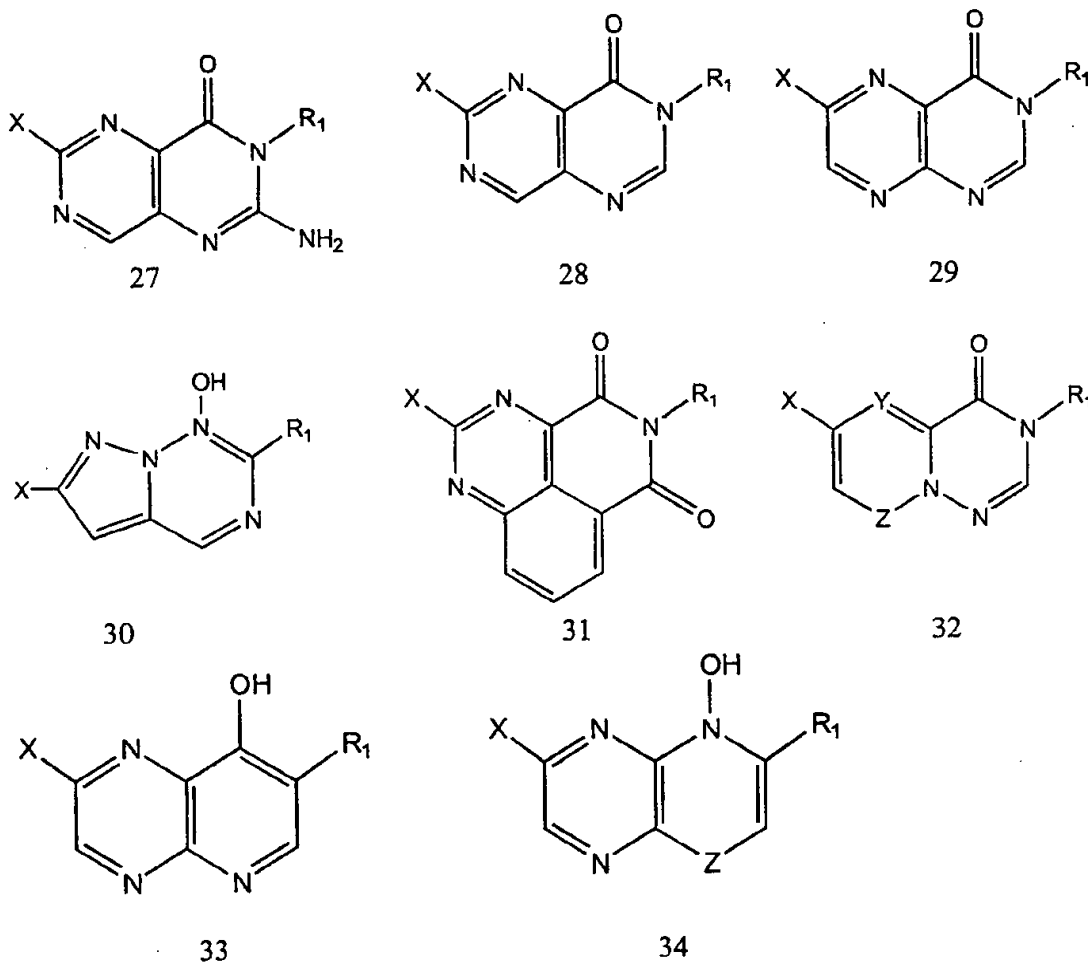


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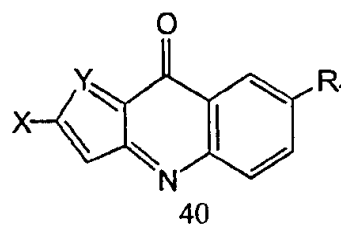
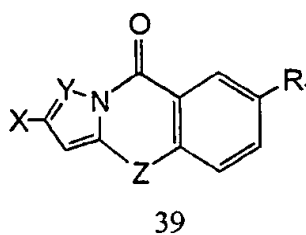
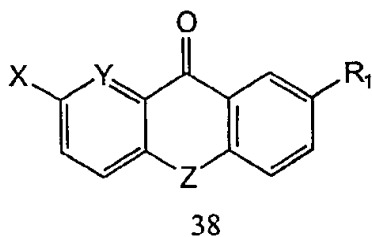
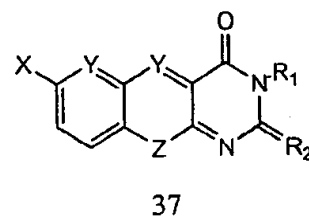
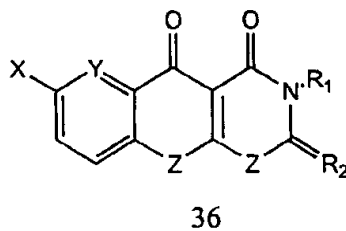
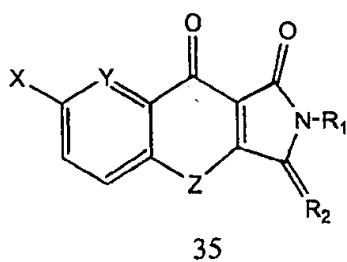
In each of Formulas 6-34, R_1 , X and Y have the meanings given above for these variables in Formula 1. In Formulas 6, and 9-15, Z is selected from the group consisting of O, S, NH, N-alkyl, N-cycloalkyl and N-P, wherein P is a

10 carbohydrate moiety, preferably a monosaccharide moiety, such as a fucosyl, glucosyl, galactosyl, mannosyl, fructosyl, gulosyl, idosyl, talosyl, allosyl, altrosyl, ribosyl, arabinosyl, xylosyl or lyxosyl group. In Formulas 6, 7, 9, 10 and 12-17, R_2 is selected from the group consisting of O, S, CH_2 and NR_3 , wherein R_3 is H, OH, aryl or alkyl.

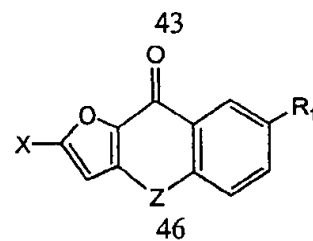
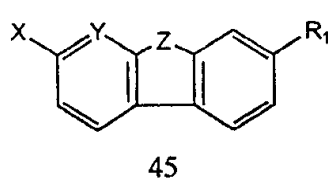
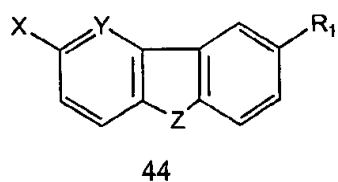
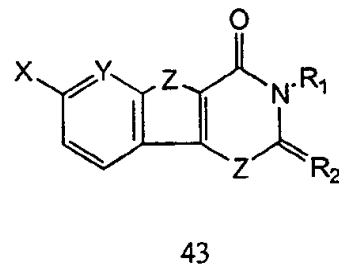
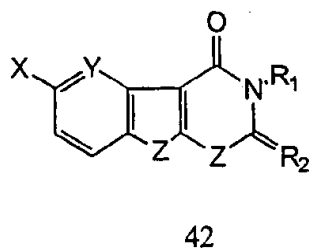
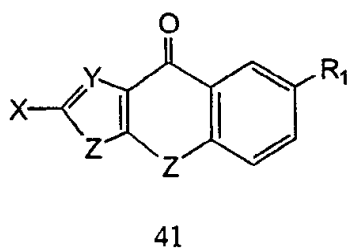
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Preferred compounds of Formulas 2 and 5 are of Formulas 35-49 below.

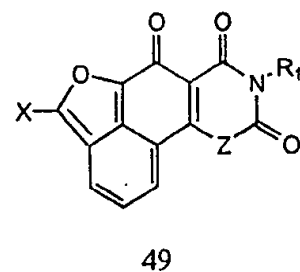
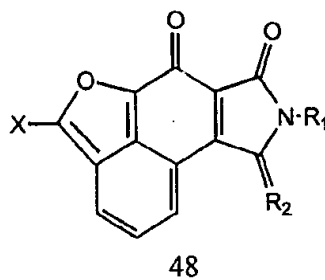
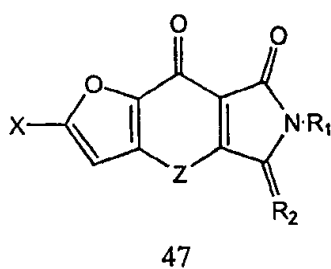
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5



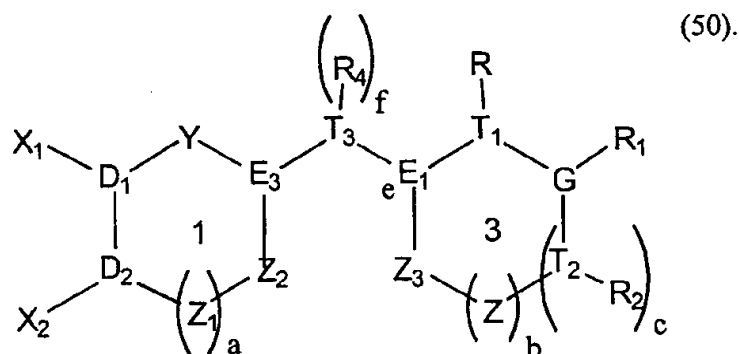
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In Formulas 32-46, the structural variables X, R₁, R₂, Z and Y each have the identities given previously for Formula 2.

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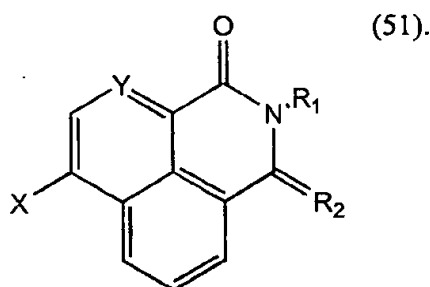
In another embodiment, the NGF/p75^{NTR} binding inhibitor is of general formula 50,



In Formula 50, the structural variables D₁, D₂, X₁, X₂, E₁, E₂, E₃, T₁, T₂, T₃, Z, G, R, R₁, R₂, R₄, b, and c have the meanings given for these variables in Formula 2. T₃ is an sp²- or sp³-hybridized carbon or nitrogen atom, and is preferably an sp²-hybridized carbon or nitrogen atom.

A preferred subset of compounds of Formula 3 is represented by Formula 51,

10



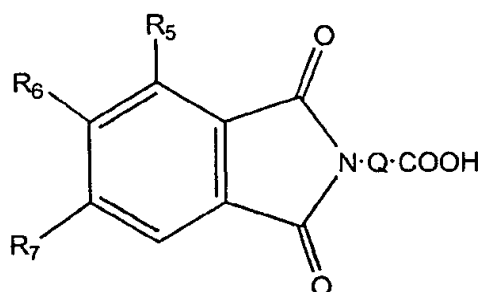
In Formula 51, X, Y and R₁ each have the meanings given for these variables in Formula 1. R₂ is O, S, CH₂ or N-R₃, wherein R₃ is H, OH, alkyl, preferably normal or branched C₁-C₆-alkyl, or aryl, such as phenyl or substituted phenyl.

In a preferred embodiment, the NGF/p75^{NTR} inhibitor exhibits greater NGF/p75^{NTR} binding inhibition in cells which express p75^{NTR} but not trkA than in cells which express both p75^{NTR} and trkA. The binding of NGF to p75^{NTR} in cells which do not express trkA can, under certain conditions, mediate apoptotic cell death. The p75^{NTR} receptor has a greater affinity for NGF in this proapoptotic

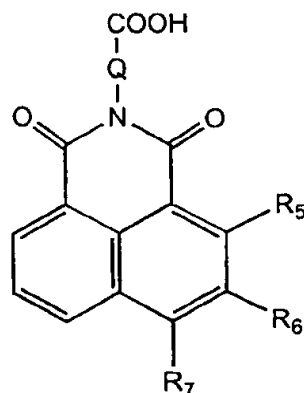
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state, that is, in cells which do not express trkA. Compounds which exhibit greater NGF/p75^{NTR} binding inhibition in the absence of trkA advantageously selectively inhibit or interfere with processes such as apoptotic cell death, while having a smaller effect on other p75^{NTR}-mediated processes.

- 5 Preferred compounds which selectively inhibit the binding of NGF to p75^{NTR} in cells which do not express trkA include compounds of Formulas 52 and 53, below.



52



53

- 10 In Formulas 52 and 53, Q is selected from the group consisting of C₁-C₅-alkylene; para- and meta-phenylene; cycloalkylene, carbohydrate and para- and meta-CH₂C₆H₄-. In Formulas 51 and 52, R₅, R₆ and R₇ are, preferably, each, independently, H, -COOH or -NO₂. More preferably, two of R₅, R₆ and R₇ are H and the other is -COOH or -NO₂.
- 15 The present invention also relates to a method of inhibiting the binding of NGF to p75^{NTR}. The method comprises contacting NGF in the presence of p75^{NTR} with an NGF/p75^{NTR} binding inhibitory amount of a NGF/p75^{NTR} inhibitor compound, thereby inhibiting binding of NGF to p75^{NTR}. The method can be practiced *in vitro*, for example, in a cell culture screening assay to screen
- 20 compounds which potentially bind, activate or inhibit receptor function.. In such a method, the inhibitor compound can function by binding and eliminating any competing function of NGF in the sample or culture. The inhibitor compounds can also be used to control NGF activity in neuronal cell culture. The method can

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also be practised *in vivo*, for example, to inhibit one or more processes mediated by binding of NGF to p75^{NTR}.

In another embodiment, the invention provides a method of treating a condition mediated by NGF/p75^{NTR} binding in a patient. The method comprises
5 the step of administering to the patient a therapeutically effective amount of a NGF/p75^{NTR} binding inhibitor, such as any of the inhibitors described above. The condition to be treated can be any condition which is mediated, at least in part, by binding of NGF to the p75^{NTR} receptor. Such conditions include, but are not limited to, Alzheimer's disease, epilepsy, pain, multiple sclerosis, amyotrophic
10 lateral sclerosis, stroke and cerebral ischemia.

Preferably, the NGF/p75^{NTR} binding inhibitor to be administered selectively inhibits the binding of NGF to p75^{NTR} in cells which do not express trkA. In this embodiment, the condition is mediated, at least in part, by the binding of NGF to the p75^{NTR} receptor in cells which do not express the trkA
15 receptor. Generally, such conditions are mediated by NGF-induced apoptotic cell death.

The quantity of a given compound to be administered will be determined on an individual basis and will be determined, at least in part, by consideration of the individual's size, the severity of symptoms to be treated and the result sought.
20 The NGF/p75^{NTR} binding inhibitor can be administered alone or in a pharmaceutical composition comprising the inhibitor, an acceptable carrier or diluent and, optionally, one or more additional drugs.

The NGF/p75^{NTR} binding inhibitor can be administered subcutaneously, intravenously, parenterally, intraperitoneally, intradermally, intramuscularly,
25 topically, enteral (e.g., orally), rectally, nasally, buccally, sublingually, vaginally, by inhalation spray, by drug pump or via an implanted reservoir in dosage formulations containing conventional non-toxic, physiologically acceptable carriers or vehicles. The preferred method of administration is by oral delivery. The form in which it is administered (e.g., syrup, elixir, capsule, tablet, solution,
30 foams, emulsion, gel, sol) will depend in part on the route by which it is administered. For example, for mucosal (e.g., oral mucosa, rectal, intestinal mucosa, bronchial mucosa) administration, nose drops, aerosols, inhalants,

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nebulizers, eye drops or suppositories can be used. The compounds and agents of this invention can be administered together with other biologically active agents, such as analgesics, anti-inflammatory agents, anesthetics and other agents which can control one or more symptoms or causes of a p75^{NTR}-mediated condition.

- 5 In a specific embodiment, it may be desirable to administer the agents of the invention locally to a localized area in need of treatment; this may be achieved by, for example, and not by way of limitation, local infusion during surgery, topical application, transdermal patches, by injection, by means of a catheter, by means of a suppository, or by means of an implant, said implant being of a porous, 10 non-porous, or gelatinous material, including membranes, such as sialastic membranes or fibers. For example, the agent can be injected into the joints.

- The compound of the invention can, optionally, be administered in combination with one or more additional drugs which, for example, are known for treating and/or alleviating symptoms of the condition mediated by p75^{NTR}. The 15 additional drug can be administered simultaneously with the compound of the invention, or sequentially.

- The present invention also provides pharmaceutical compositions. Such compositions comprise a therapeutically (or prophylactically) effective amount of one or more NGF/p75^{NTR} binding inhibitors, preferably one or more compounds of 20 Formulas 1, 2, 4 or 5, as described above, and a pharmaceutically acceptable carrier or excipient. Suitable pharmaceutically acceptable carriers include, but are not limited to, saline, buffered saline, dextrose, water, glycerol, ethanol, and combinations thereof. The carrier and composition can be sterile. The formulation should suit the mode of administration.

- 25 Suitable pharmaceutically acceptable carriers include but are not limited to water, salt solutions (e.g., NaCl), alcohols, gum arabic, vegetable oils, benzyl alcohols, polyethylene glycols, gelatin, carbohydrates such as lactose, amylose or starch, cyclodextrin, magnesium stearate, talc, silicic acid, viscous paraffin, perfume oil, fatty acid esters, hydroxymethylcellulose, polyvinyl pyrrolidone, etc. 30 The pharmaceutical preparations can be sterilized and if desired, mixed with auxiliary agents, e.g., lubricants, preservatives, stabilizers, wetting agents, emulsifiers, salts for influencing osmotic pressure, buffers, coloring, flavoring

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and/or aromatic substances and the like which do not deleteriously react with the active compounds.

The composition, if desired, can also contain minor amounts of wetting or emulsifying agents, or pH buffering agents. The composition can be a liquid
5 solution, suspension, emulsion, tablet, pill, capsule, sustained release formulation, or powder. The composition can be formulated as a suppository, with traditional binders and carriers such as triglycerides. Oral formulation can include standard carriers such as pharmaceutical grades of mannitol, lactose, starch, magnesium stearate, polyvinyl pyrrolidone, sodium saccharine, cellulose, magnesium
10 carbonate, etc.

The composition can be formulated in accordance with the routine procedures as a pharmaceutical composition adapted for intravenous administration to human beings. Typically, compositions for intravenous administration are solutions in sterile isotonic aqueous buffer. Where necessary,
15 the composition may also include a solubilizing agent and a local anesthetic to ease pain at the site of the injection. Generally, the ingredients are supplied either separately or mixed together in unit dosage form, for example, as a dry lyophilized powder or water free concentrate in a hermetically sealed container such as an ampule or sachet indicating the quantity of active agent. Where the composition is
20 to be administered by infusion, it can be dispensed with an infusion bottle containing sterile pharmaceutical grade water, saline or dextrose/water. Where the composition is administered by injection, an ampule of sterile water for injection or saline can be provided so that the ingredients may be mixed prior to administration.

25 The pharmaceutical compositions of the invention can also include an agent which controls release of the NGF/p75^{NTR} inhibitor compound, thereby providing a timed or sustained release composition.

The present invention also relates to prodrugs of the NGF/p75^{NTR} binding inhibitors disclosed herein, as well as pharmaceutical compositions comprising
30 such prodrugs. For example, compounds of the invention which include acid functional groups or hydroxyl groups can also be prepared and administered as a

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corresponding ester with a suitable alcohol or acid. The ester can then be cleaved by endogenous enzymes within the patient to produce the active agent.

In a further embodiment, the invention relates to the use of an NGF/p75^{NTR} binding inhibitor, such as any of the compounds described above, for treating a condition mediated by binding of NGF to p75^{NTR}. The invention further relates to the use of these compounds for the manufacture of a medicament for treating a condition mediated by binding of NGF to p75^{NTR}.

Representative syntheses of compounds of the invention are set forth in the following examples. Other synthetic pathways that can be used to prepare certain compounds of the invention are illustrated in Figs. 3 and 4.

EXAMPLES

Example 1 - Synthesis of NGF/p75^{NTR} inhibitors

General methods

Reagents and solvents were obtained from commercial sources (Sigma, Aldrich, BDH). THF was dried by refluxing with benzophenone and potassium and subsequently distilled. All other solvents were utilized as they were received.

Thin layer chromatography (TLC) solvent systems used are given in Table 1. These were developed by ascending TLC on precoated aluminum backed sheets of silica gel 60 F254 (Merck). TLC plates were developed using ultra-violet light, iodine crystal and/or ninhydrin.

Melting points (mp) were determined on a Thomas Hoover Unimelt melting point apparatus and are uncorrected.

NMR spectra of final compounds were determined on an AVANCE 300 MHz NMR spectrometer. All NMR samples were prepared in DMSO-d₆ unless otherwise indicated. Chemical shifts are reported as δ parts per million using DMSO as an internal reference. Mass spectrometric (MS) analyses are performed on a Varian Instrument VG Quattro multiple quadrupole spectrometer using electrospray ionization (ESI). The spectra were all obtained in the negative ion mode. IR spectra were recorded on a Bomem MB-120 FT-IR spectrophotometer.

Abbreviations used herein are: HOAc, glacial acetic acid; THF, tetrahydrofuran; DMSO-d₆, deuterated dimethylsulfoxide; CHCl₃, chloroform;

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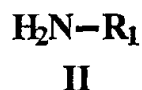
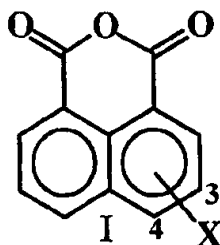
MeCN, acetonitrile; H₂O, distilled water; MeOH, methanol; EtOH, ethanol; TEA, triethylamine; EtOAc, ethyl acetate.

Table 1: List of Solvent Systems.

Solvent Code	Solvent System	Solvent Ratio
A	MeOH:HOAc	5:1
B	MeCN:H ₂ O:MeOH	8:1:1
C	MeCN:H ₂ O:MeOH	4:1:1
D	CHCl ₃ :MeOH:HOAc	95:10:3
E	EtOH:HOAc	50:1

General Synthesis of Naphthalimide derivatives

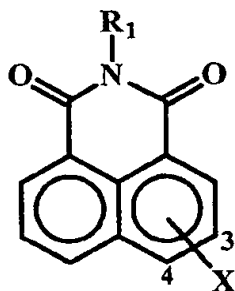
Method A: The naphthalimide series of compounds was prepared through the condensation of stoichiometric amounts of 1,8-naphthalic anhydride or its derivative (I) with an appropriate primary amine (II). The combined reagents were dissolved in glacial acetic acid, dry THF, dry 1,4-dioxane or DMSO and placed under a N₂ atmosphere and refluxed. The progress of the reaction was monitored by TLC. Final clear solutions were concentrated *in vacuo* and the resulting crude material was either reprecipitated from 1,4-dioxane/1N HCl or HOAc/H₂O and/or recrystallized from 95% ethanol, THF or 1,4-dioxane. In the instances where the final product precipitated out of the reaction solution, the completed reaction mixture was cooled to room temperature, the solid collected by filtration and washed with distilled water. This precipitate was reprecipitated with 1,4-dioxane/ 1N HCl or HOAc/H₂O and/or recrystallized from 95% ethanol, THF or 1,4-dioxane. Purification also included fractional recrystallisation.



where X and R₁ are as previously defined.

Method B: Reaction conditions and purification procedures were similar to those of method A. However, instead of stoichiometric amounts of reagents, the anhydride (I) and the primary amine(II) were combined in a 1:2 ratio with the optional addition of 1 equivalent of anhydrous sodium acetate. During the course of preparing the various naphthalimide derivatives, these reaction conditions were found to lead to increased product yields. Glacial acetic acid was the solvent of choice used under these conditions.

Table 2: Synthesized Naphthalimide Derivatives



Compd.	X	R ₁	Name
200	3-NO ₂	CH ₂ COOH	N-(1-carboxymethyl)-3-nitro-1,8-naphthalimide; 2-(1-carboxymethyl)-5-nitrobenzo[d,e]isoquinoline-1,3-dione
201	3-NO ₂	CH ₂ CH ₂ COOH	N-(2-carboxyethyl)-3-nitro-1,8-naphthalimide; 2-(2-carboxyethyl)-5-nitrobenzo[d,e]isoquinoline-1,3-dione
202	3-NO ₂	CH ₂ (CH ₂) ₂ COOH	N-(3-carboxypropyl)-3-nitro-1,8-naphthalimide; 2-(3-carboxypropyl)-5-nitrobenzo[d,e]isoquinoline-1,3-dione
203	3-NO ₂	CH ₂ (CH ₂) ₃ COOH	N-(4-carboxybutyl)-3-nitro-1,8-naphthalimide; 2-(4-carboxybutyl)-5-nitrobenzo[d,e]isoquinoline-1,3-dione
204	3-NO ₂	CH ₂ (CH ₂) ₄ COOH	N-(5-carboxypentyl)-3-nitro-1,8-naphthalimide; 2-(5-carboxypentyl)-5-nitrobenzo[d,e]isoquinoline-1,3-dione

Compd.	X	R ₁	Name
220	4-NO ₂	CH ₂ COOH	N-(1-carboxymethyl)-4-nitro-1,8-naphthalimide; 2-(1-carboxymethyl)-6-nitrobenzo[d,e]isoquinoline-1,3-dione
221	4-NO ₂	CH ₂ CH ₂ COOH	N-(2-carboxyethyl)-4-nitro-1,8-naphthalimide; 2-(2-carboxyethyl)-6-nitrobenzo[d,e]isoquinoline-1,3-dione
222	4-NO ₂	CH ₂ (CH ₂) ₂ COOH	N-(3-carboxypropyl)-4-nitro-1,8-naphthalimide; 2-(3-carboxypropyl)-6-nitrobenzo[d,e]isoquinoline-1,3-dione
223	4-NO ₂	CH ₂ (CH ₂) ₃ COOH	N-(4-carboxybutyl)-4-nitro-1,8-naphthalimide; 2-(4-carboxybutyl)-6-nitrobenzo[d,e]isoquinoline-1,3-dione
224	4-NO ₂	CH ₂ (CH ₂) ₄ COOH	N-(5-carboxypentyl)-4-nitro-1,8-naphthalimide; 2-(5-carboxypentyl)-6-nitrobenzo[d,e]isoquinoline-1,3-dione

Naphthalimide Derivatives:

Method A:

N-(1-carboxymethyl)-3-nitro-1,8-naphthalimide (200)

- 3-nitro-1,8-naphthalic anhydride (1.0 g, 0.0041 mol) and glycine (0.31 g, 0.0041 mol) and 50-60 mls of glacial acetic acid were added to a 100 ml round-bottom flask equipped with a reflux condenser, heating mantle and stir plate. The system was placed under a N₂ atmosphere and heated to a gentle reflux. The progress of the reaction was monitored by TLC. After four days, the clear dark amber solution was concentrated under vacuum and the crude brown material reprecipitated with 1,4-dioxane/ 1N HCl. The precipitate was filtered through a Buchner funnel and washed with water. Successive fractional recrystallizations in ethanol afforded 0.35g (28%) of 200 as a beige powder: M. Pt. 260-262°C; TLC R_f 0.83 (A): R_f 0.82 (B): R_f 0.23 (D): ¹H NMR (DMSO-*d*₆): IR (cm⁻¹): 2750-3100 (OH), 3077 (C=CH), 2665 (C-H), 1732 (C=O), 1711 (bs, C=O), 1670 (C=O), 1597 (C=C), 1538 (N=O), 1509 (C=C), 1430 (C=C), 1372 (C-O), 1341 (N-O), 1244

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(C-O), 787 (C=CH). MS *m/z* (rel intensity) 299 (97) 255 (100), 281 (93), 172 (26).

N-(2-carboxyethyl)-3-nitro-1,8-naphthalimide (201)

3-nitro-1,8-naphthalic anhydride (1.0 g, 0.0041 mol) and β -alanine (0.37, 0.0041 mol) were refluxed as per 200 for 48 hours. Precipitate that formed during
5 the course of the reaction was filtered and washed with water. The filtrate was concentrated under vacuum and the crude brown material reprecipitated with 1,4-dioxane/1N HCl. The precipitate was filtered through a Buchner funnel and washed with water. Both solids were combined and triturated with hot ethanol and 1,4-dioxane. Any undissolved material was removed by filtration. The combined
10 ethanol and 1,4-dioxane fractions were concentrated *in vacuo*. Crystallization from ethanol afforded 0.38 g (30%) of 201 as a beige powder: M. Pt. 246-248°C; TLC R_f 0.74 (A): R_f 0.84 (B): R_f 0.67 (D): ^1H NMR (DMSO- d_6); IR (cm^{-1}): 2800-3130 (OH), 3071 (C=CH), 2646 (C-H), 1707 (bs, C=O), 1663 (C=O), 1625 (C=C), 1597 (C=C), 1537 (N=O), 1439 (C=C), 1420 (C=C), 1369 (C-O), 1347 (N-
15 O), 1243 (C-O), 789 (C=CH). MS *m/z* (rel intensity) 313 (100) 241 (42).

N-(3-carboxypropyl)-3-nitro-1,8-naphthalimide (202)

3-nitro-1,8-naphthalic anhydride (1.0 g, 0.0041 mol) and 4-aminobutyric acid (0.42 g, 0.0041 mol) were refluxed as per 200 for 48 hours. Resultant
20 solution was purified as per 201 to afford 0.55 g (42%) of 202 as a fluffy beige solid: M. Pt. 200-202°C; TLC R_f 0.88 (A): R_f 0.85 (B): R_f 0.75 (D): ^1H NMR (DMSO- d_6); IR (cm^{-1}): 2875-3100 (OH), 3062 (C=CH), 2560 (C-H), 1785 (C=O), 1702 (C=O), 1658 (C=O), 1625 (C=C), 1595 (C=C), 1538 (N=O), 1438 (C=C), 1418 (C=C), 1372
25 (C-O), 1334 (N-O), 1244 (C-O), 789 (C=CH). MS *m/z* (rel intensity) 327 (100) 241 (40).

N-(4-carboxybutyl)-3-nitro-1,8-naphthalimide (203)

3-nitro-1,8-naphthalic anhydride (0.5 g, 0.0020 mol) and 5-aminopentanoic acid (0.24 g, 0.0020 mol) were refluxed in DMSO as per 200 for 24 hours. The

dark orange brown solution was diluted with water until a beige precipitate formed. The precipitate was filtered through a Buchner funnel and washed copiously with water. The process was repeated on the concentrated filtrate. Combined solids were recrystallized in 1,4-dioxane/1N HCl. The filtered product

- 5 was dried in air for a short time and then *in vacuo* for 48-72 hours to afford 0.43 g (63%) 203 as a beige feathery solid: M. Pt. 203-205°C; TLC R_f 0.92 (A): R_f 0.89 (C): R_f 0.26 (D): ^1H NMR (DMSO- d_6): IR (cm^{-1}): 2700-3130 (OH), 3066 (C=CH), 1784 (C=O), 1706 (bs, C=O), 1659 (C=O), 1625 (C=C), 1596 (C=C), 1541 (N=O), 1458 (C=C), 1438 (C=C), 1351 (N-O), 1245 (C-O), 789 (C=CH).
10 MS m/z (rel intensity) 341 (100), 241 (16), 216 (24).

N-(5-carboxypentyl)-3-nitro-1,8-naphthalimide (204)

- 3-nitro-1,8-naphthalic anhydride (1.0 g, 0.0041 mol) and 6-aminoheptanoic acid (0.54 g, 0.0041 mol) were refluxed in 100 ml THF and 10ml DMSO as per 200 for 24 hours. The dark brown solution was concentrated and manipulated as
15 per 203 to yield 1.0 g (67 %) 204 as beige powder: M. Pt. 192-194°C; TLC R_f 0.70 (A): R_f 0.91 (B): R_f 0.63 (D): ^1H NMR (DMSO- d_6) δ 1.36 (m, 2H), 1.54 (m, 2H), 1.64 (m, 2H), 2.22 (t, $J=7.3$ Hz, 2H), 4.02 (t, $J=7.3$ Hz, 2H), 8.02 (dd, $J=7.1$, 8.3 Hz, 1H), 8.63 (d, $J=7.1$ Hz, 1H), 8.73 (d, $J=8.3$ Hz, 1H), 8.89 (d, $J=2.3$ Hz, 1H), 9.43 (d, $J=2.3$ Hz, 1H); IR (cm^{-1}): 2700-3175 (OH), 3075 (C=CH), 2688 (C-
20 H), 1706 (bs, C=O), 1663 (C=O), 1625 (C=C), 1598 (C=C), 1533 (N=O), 1437 (C=C), 1419 (C=C), 1348 (N-O), 1244 (C-O), 791 (C=CH). MS m/z (rel intensity) 355 (100).

N-(2-carboxyethyl)-4-nitro-1,8-naphthalimide (221)

- 4-nitro-1,8-naphthalic anhydride (0.5 g, 0.0020 mol) and β -alanine (0.18
25 g, 0.0020 mol) were refluxed for 4 days and the final mixture purified as per 200. Successive fractional recrystallisations in CHCl_3 afforded 0.24 g (38%) 221 as an beige solid: M. Pt. 224-225 °C; TLC R_f 0.77 (A): R_f 0.80 (C): R_f 0.46 (D): ^1H NMR (DMSO- d_6): IR (cm^{-1}): 2800-3175 (OH), 3077 (C=CH), 2637 (C-H), 1788 (C=O), 1705 (bs, C=O), 1657 (C=O), 1624 (C=C), 1594 (C=C), 1534 (N=O),

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1440 (C=C), 1408 (C=C), 1346 (N-O), 1229 (C-O), 789 (C=CH). MS *m/z* (rel intensity) 314 (16), 313 (100), 274 (50).

N-(3-carboxypropyl)-4-nitro-1,8-naphthalimide (222)

- 4-nitro-1,8-naphthalic anhydride (0.5 g, 0.0020 mol) and 4-aminobutyric acid (0.21 g, 0.0020 mol) were refluxed for 5 days in dry THF as per 200. The dark orange amber solution was concentrated to 20 ml *in vacuo* and diluted with 1N HCl until a beige precipitate formed. The precipitate was filtered through a Buchner funnel and washed with water. The crude material was reprecipitated from 1,4-dioxane/1N HCl and filtered. Successive fractional recrystallisations in CHCl₃ afforded 0.22 g (34%) of 222 as a beige solid: M. Pt. 179-180 °C; R_f 0.85 (A): TLC R_f 0.81 (B): R_f 0.48 (D): ¹H NMR (DMSO-*d*₆): IR (cm⁻¹): 2780-3200 (OH), 3075 (C=CH), 2688 (C-H), 1778 (C=O), 1705 (bs, C=O), 1655 (C=O), 1624 (C=C), 1584 (C=C), 1534 (N=O), 1439 (C=C), 1409 (C=C), 1344 (N-O), 1231 (C-O), 789 (C=CH). MS *m/z* (rel intensity) 328 (20), 327 (100), 274 (27), 241 (36).

N-(4-carboxybutyl)-4-nitro-1,8-naphthalimide (223)

- 4-nitro-1,8-naphthalic anhydride (0.5 g, 0.0020 mol) and 5-aminopentanoic acid (0.24 g, 0.0020 mol) were refluxed for 3 days in dry THF as per 200. The dark orange amber solution was purified as per 222 to afford 0.27 g (40%) of 223 as an orange powder: M. Pt. 198-200 °C; TLC R_f 0.84 (A): R_f 0.88 (C): R_f 0.46 (D): ¹H NMR (DMSO-*d*₆): IR (cm⁻¹): 2825-3130 (OH), 3077 (C=CH), 2670 (C-H), 1704 (bs, C=O), 1660 (C=O), 1624 (C=C), 1583 (C=C), 1529 (N=O), 1435 (C=C), 1411 (C=C), 1345 (N-O), 1233 (C-O), 787 (C=CH). MS *m/z* (rel intensity) 342 (19), 341 (100), 274 (20), 241 (40).

N-(5-carboxypentyl)-4-nitro-1,8-naphthalimide (224)

4-nitro-1,8-naphthalic anhydride (0.5 g, 0.0020 mol) and 6-aminohexanoic acid (0.27 g, 0.0020 mol) were refluxed for 3 days in dry THF and the final mixture purified as per 223. Crystallization from THF/1N HCl afforded 0.65 g (95%) of 224 as a beige solid: M. Pt. 168-169 °C; TLC R_f 0.85 (A): R_f 0.81 (B):

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R_f 0.50 (D): ¹H NMR (DMSO-*d*₆): IR (cm⁻¹): 2775-3175 (OH), 3078 (C=CH), 2670 (C-H), 1716 (bs, C=O), 1661 (C=O), 1624 (C=C), 1594 (C=C), 1521 (N=O), 1436 (C=C), 1409 (C=C), 1339 (N-O), 1261 (C-O), 785 (C=CH). MS *m/z* (rel intensity) 365 (21), 355 (100).

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Method B:

N-(1-carboxymethyl)-4-nitro-1,8-naphthalimide (220)

4-nitro-1,8-naphthalic anhydride (1.0 g, 0.0041 mol), glycine (0.38 g, 0.0082 mol), anhydrous sodium acetate (0.51 g, 0.61 mol) and 70-80 mls of glacial acetic acid were added to a 100 ml round-bottom flask equipped with a reflux condenser, heating mantle and stir plate. The system was placed under a N₂ atmosphere and heated to a gentle reflux. After 3 days, the dark amber solution was concentrated to 15-20 ml under vacuum with a rotary evaporator. Ensuing precipitate was filtered and washed twice with 5 ml 1N HCl and twice with 5 ml water. Crystallization from 1,4-dioxane/H₂O afforded 0.6 g (50%) 220 as a beige solid: M. Pt. 263-264°C; TLC R_f 0.81 (A): R_f 0.84 (C): R_f 0.35 (D): ¹H NMR (DMSO-*d*₆) δ 4.74 (s, 2H), 8.10 (dd, *J*=8.4, 8.0 Hz, 1H), 8.55 (d, *J*=7.6 Hz, 1H), 8.63 (d, *J*=8.0 Hz, 1H), 8.65 (d, *J*=8.0, 1H), 8.73 (d, *J*=8.4 Hz, 1H); IR (cm⁻¹): 2850-3150 (OH), 3077 (C=CH), 2671 (C-H), 1711 (C=O), 1674 (bs, C=O), 1625 (C=C), 1583 (C=C), 1531 (N=O), 1429 (C=C), 1334 (N-O), 1232 (C-O), 785 (C=CH). MS *m/z* (rel intensity) 299 (100), 255 (280).

Example 2 - Assessment of NGF/p75^{NTR} binding inhibition

The radio-iodination and receptor binding of NGF (Sutter et al., 1979) was performed with modifications (Ross et al., 1997) as follows: Evaluation of the ability of NCP compounds to inhibit TrkA and p75^{NTR} binding was determined by the binding of ¹²⁵I-NGF to PC12 cells (rat pheochromocytoma cells expressing TrkA and p75^{NTR}; obtained from ATCC) and PC12^{nmr5} (rat pheochromocytoma cells expressing p75^{NTR} only; obtained from Dr. L. Greene, Columbia University, NY). The p75^{NTR} is in a low affinity state and a high affinity state, respectively, in these cell types (Ross et al., 1998). PC12 and PC12^{nmr5} cells were grown in RPMI (Sigma) with 10% heat inactivated donor horse serum and 5% fetal calf serum. Cells were harvested by replacing the medium with calcium, magnesium-free balanced salt solution (Gey's solution) and incubating at 37°C for 15 minutes. Cells were pelleted by centrifugation and suspended in HKR buffer (10 mM Hepes [pH 7.35] containing 125 mM NaCl, 4.8 mM KCl, 1.3 mM CaCl₂, 1.2 mM MgSO₄, 1.2 mM KH₂PO₄, 1g/L glucose and 1g/L BSA) at a cell concentration of

2x10⁶/mL and kept at 4°C. Triplicate tubes were set up for total binding, non-specific binding and binding in the presence of candidate competitor molecule (i.e., a tube for each data point). Each tube contained ¹²⁵I-NGF (at 1 nM), 400,000 cells (for a final cell concentration of 10⁶/mL) and NGF (50 nM, to define non-specific binding), as required. The tubes were incubated for 2 h at 4°C and specific binding evaluated by measuring specifically bound DPM (Ross et al., 1997). Data were analysed and the results expressed as receptor binding observed in the presence of competitor as a percentage of receptor binding in the absence of a competitor.

Table 3: Results of in vitro binding inhibition assays

Compound (50µM)	PC12 % of Max	nnr5 % of Max
200	92, 87, 74 = 84	58, 63, 64 = 62
201	27, 32, 41 = 33	30, 4, 34 = 23
202	21, 22, 30 = 24	16, 0, 0 = 5
203	36, 41, 35 = 37	33, 0, 18 = 17
204	41, 41, 36 = 39	12, 0, 47 = 20
220 NS	37, 43, 49 = 43	21, 17, 26 = 21
221	29, 32, 31 = 31	41, 37, 42 = 40
222 NS	NT	NT
223	27, 33, 33 = 31	40, 41, 47 = 43
224	31, 34, 22 = 29	36, 35, 39 = 36

NS: Not Soluble @ 100µM DMSO

NT: Not Tested

While this invention has been particularly shown and described with references to preferred embodiments thereof, it will be understood by those skilled in the art that various changes in form and details may be made therein without

departing from the spirit and scope of the invention as defined by the appended claims.

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CLAIMS

What is claimed is:

1. A compound which inhibits the binding of nerve growth factor to the p75^{NTR} receptor, said compound being characterized by at least two of:
 - 5 (a) a first electronegative atom positioned to interact with Lys³⁴ of nerve growth factor;
 - (b) a second electronegative atom positioned to interact with Lys⁹⁵ of nerve growth factor;
 - (c) a third electronegative atom positioned to interact with Lys⁸⁸ of
10 nerve growth factor;
 - (d) a fourth electronegative atom positioned to interact with Lys³² of nerve growth factor; and
 - (e) a hydrophobic moiety which interacts with the hydrophobic region formed by Ile³¹, Phe¹⁰¹ and Phe⁸⁶ of nerve growth factor.
- 15 2. A method of inhibiting the binding of nerve growth factor to the p75^{NTR} receptor, comprising contacting the cells expressing the p75^{NTR} receptor with an effective inhibiting amount of a compound which is characterized by
 - 20 (a) a first electronegative atom positioned to interact with Lys³⁴ of nerve growth factor;
 - (b) a second electronegative atom positioned to interact with Lys⁹⁵ of nerve growth factor;
 - (c) a third electronegative atom positioned to interact with Lys⁸⁸ of nerve growth factor;
 - 25 (d) a fourth electronegative atom positioned to interact with Lys³² of nerve growth factor; and
 - (e) a hydrophobic moiety which interacts with the hydrophobic region formed by Ile³¹, Phe¹⁰¹ and Phe⁸⁶ of nerve growth factor;

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thereby inhibiting the binding of nerve growth factor to the p75^{NTR} receptor.

3. A pharmaceutical composition comprising

(a) a compound which is characterized by at least two of:

- 5 (i) a first electronegative atom positioned to interact with Lys³⁴ of nerve growth factor;
- (ii) a second electronegative atom positioned to interact with Lys⁹⁵ of nerve growth factor;
- 10 (iii) a third electronegative atom positioned to interact with Lys⁸⁸ of nerve growth factor;
- (iv) a fourth electronegative atom positioned to interact with Lys³² of nerve growth factor; and
- 15 (v) a hydrophobic moiety which interacts with the hydrophobic region formed by Ile³¹, Phe¹⁰¹ and Phe⁸⁶ of nerve growth factor;

and

(b) a pharmaceutically acceptable carrier or excipient.

4. A method of treating a condition characterized by nerve growth factor-mediated cell apoptosis in a patient; said method comprising the step of

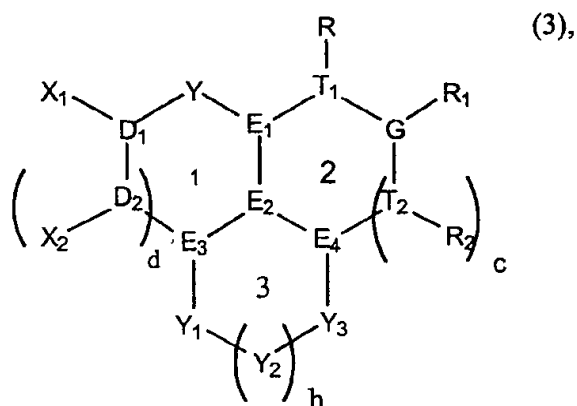
20 administering to the patient a therapeutically effective amount of a compound which is characterized by

- (a) a first electronegative atom positioned to interact with Lys³⁴ of nerve growth factor;
- 25 (b) a second electronegative atom positioned to interact with Lys⁹⁵ of nerve growth factor;
- (c) a third electronegative atom positioned to interact with Lys⁸⁸ of nerve growth factor;
- (d) a fourth electronegative atom positioned to interact with Lys³² of nerve growth factor; and

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(e) a hydrophobic moiety which interacts with the hydrophobic region formed by Ile³¹, Phe¹⁰¹ and Phe⁸⁶ of nerve growth factor; thereby inhibiting the binding of nerve growth factor to the p75^{NTR} receptor.

- 5 5. The method of Claim 4 wherein the neurotrophin-mediated condition is selected from the group consisting of Alzheimer's disease, epilepsy, multiple sclerosis, amyotrophic lateral sclerosis, stroke, and pain.
6. A method of inhibiting binding of nerve growth factor to the p75^{NTR} receptor, comprising contacting the cells expressing the p75^{NTR} receptor
- 10 with an effective inhibiting amount of a compound of Formula 3,



wherein

D₁, D₂, E₁, E₂, E₃, E₄ and G are each, independently, an sp²-hybridized carbon or nitrogen atom;

15 one of X₁ and X₂ is a hydrogen atom, while the other is an electronegative atom or an electronegative functional group;

R and R₂ are each, independently, an electronegative atom or an electronegative functional group;

Y, Y₁, Y₂, and Y₃ are each, independently, N, O, S, C-L or N-L, where L is

20 H, alkyl or an electronegative atom or functional group;

T₁ and T₂ are each, independently, an sp²- or sp³-hybridized carbon or nitrogen atom;

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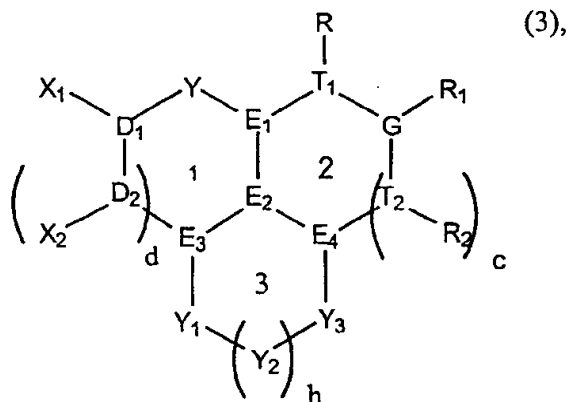
d, h and c are each 0 or 1; and

R_1 is a monocyclic or polycyclic aryl or heteroaryl group

group which is substituted with at least one substituent selected from the group consisting of hydroxyl and sulfonamide or an alkyl or alkylamino group substituted with a carboxyl or carbonate group.

7. A method of inhibiting the binding of nerve growth factor to the $p75^{NTR}$ receptor, comprising contacting the cells expressing the $p75^{NTR}$ receptor with an effective inhibiting amount of a compound of Formula 1,

10



wherein

D₁, D₂, E₁, E₂, E₃, E₄ and G are each, independently, an sp^2 -hybridized carbon or nitrogen atom;

one of X₁ and X₂ is a hydrogen atom, while the other is an electronegative atom or an electronegative functional group;

R and R₂ are each, independently, an electronegative atom or an electronegative functional group;

Y, Y₁, Y₂, and Y₃ are each, independently, N, O, S, C-L or N-L, where L is H, alkyl or an electronegative atom or functional group;

T₁ and T₂ are each, independently, an sp^2 - or sp^3 -hybridized carbon or nitrogen atom;

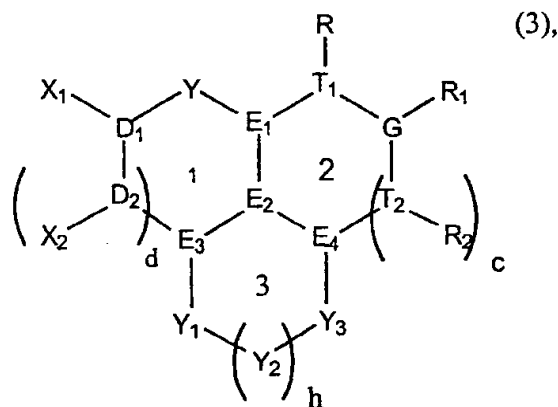
d, h and c are each 0 or 1; and

R_1 is a monocyclic or polycyclic aryl or heteroaryl group

-46-

group which is substituted with at least one substituent selected from the group consisting of hydroxyl and sulfonamide or an alkyl or alkylamino group substituted with a carboxyl or carbonate group.

- 5 8. A method of treating a condition characterized by nerve growth factor-mediated cell apoptosis in a patient; said method comprising the step of administering to the patient a therapeutically effective amount of a compound of Formula 3,

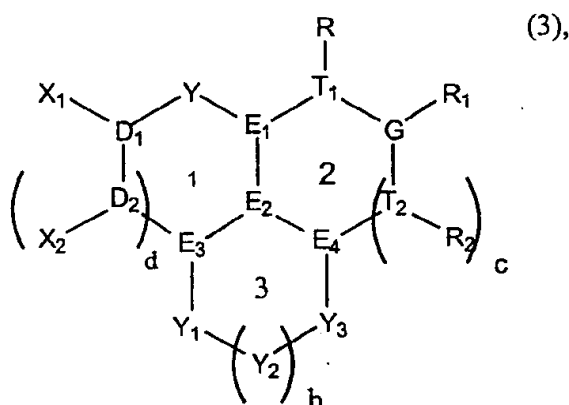


- 10 wherein
- D₁, D₂, E₁, E₂, E₃, E₄ and G are each, independently, an sp²-hybridized carbon or nitrogen atom;
- one of X₁ and X₂ is a hydrogen atom, while the other is an electronegative atom or an electronegative functional group;
- 15 R and R₂ are each, independently, an electronegative atom or an electronegative functional group;
- Y, Y₁, Y₂, and Y₃ are each, independently, N, O, S, C-L or N-L, where L is H, alkyl or an electronegative atom or functional group;
- T₁ and T₂ are each, independently, an sp²- or sp³-hybridized carbon or
- 20 nitrogen atom;
- d, h and c are each 0 or 1; and
- R₁ is a monocyclic or polycyclic aryl or heteroaryl group

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group which is substituted with at least one substituent selected from the group consisting of hydroxyl and sulfonamide or an alkyl or alkylamino group substituted with a carboxyl or carbonate group.

- 5 9. The method of Claim 8 wherein the neurotrophin-mediated condition is selected from the group consisting of Alzheimer's disease, epilepsy, multiple sclerosis, amyotrophic lateral sclerosis, stroke and pain.
10. A pharmaceutical composition comprising a compound of Formula 1,



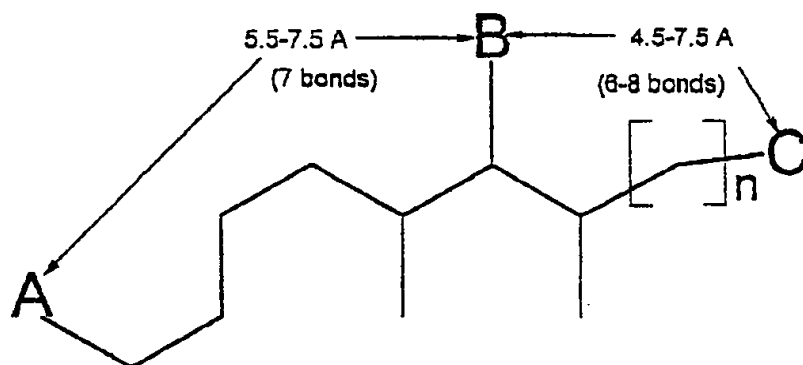
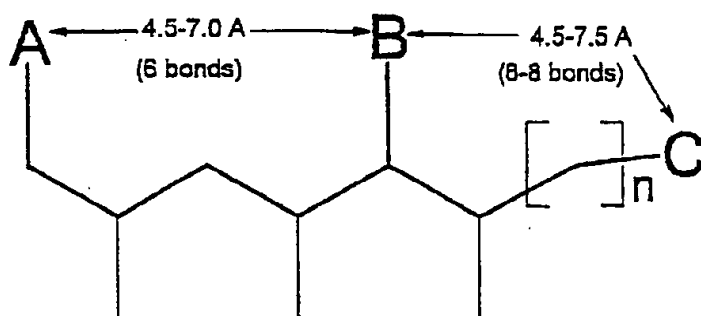
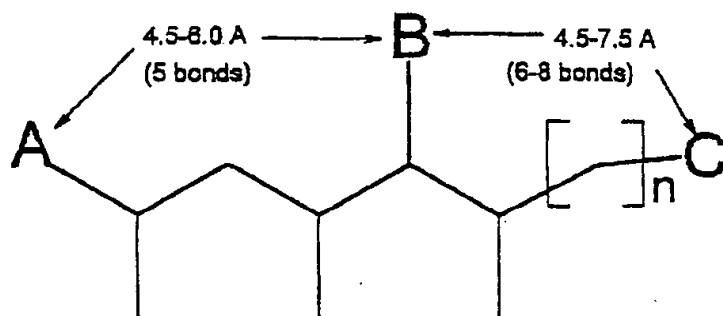
- 10 wherein
- D_1 , D_2 , E_1 , E_2 , E_3 , E_4 and G are each, independently, an sp^2 -hybridized carbon or nitrogen atom;
- one of X_1 and X_2 is a hydrogen atom, while the other is an electronegative atom or an electronegative functional group;
- 15 R and R_2 are each, independently, an electronegative atom or an electronegative functional group;
- Y , Y_1 , Y_2 , and Y_3 are each, independently, N, O, S, C-L or N-L, where L is H, alkyl or an electronegative atom or functional group;
- T_1 and T_2 are each, independently, an sp^2 - or sp^3 -hybridized carbon or
- 20 nitrogen atom;
- d , h and c are each 0 or 1; and
- R_1 is a monocyclic or polycyclic aryl or heteroaryl group

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group which is substituted with at least one substituent selected from the group consisting of hydroxyl and sulfonamide or an alkyl or alkylamino group substituted with a carboxyl or carbonate group; and

5 at least one pharmaceutically acceptable carrier or excipient.

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A-C denote electronegative atoms

$n = 3 - 5$

Fig. 1

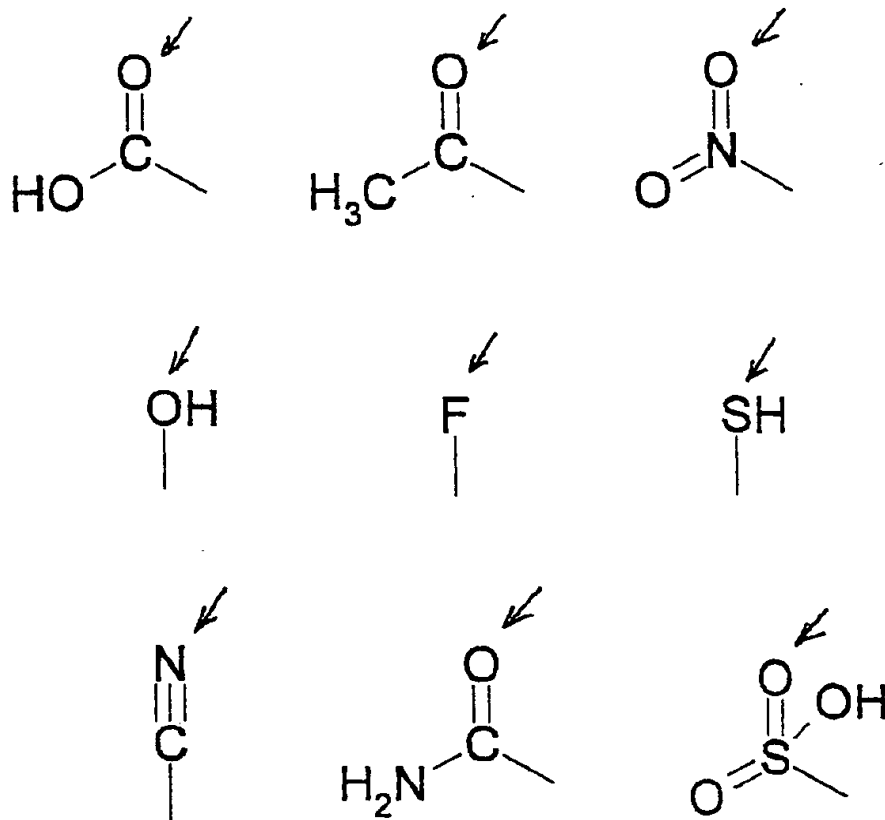


Fig. 2

Scheme 1:

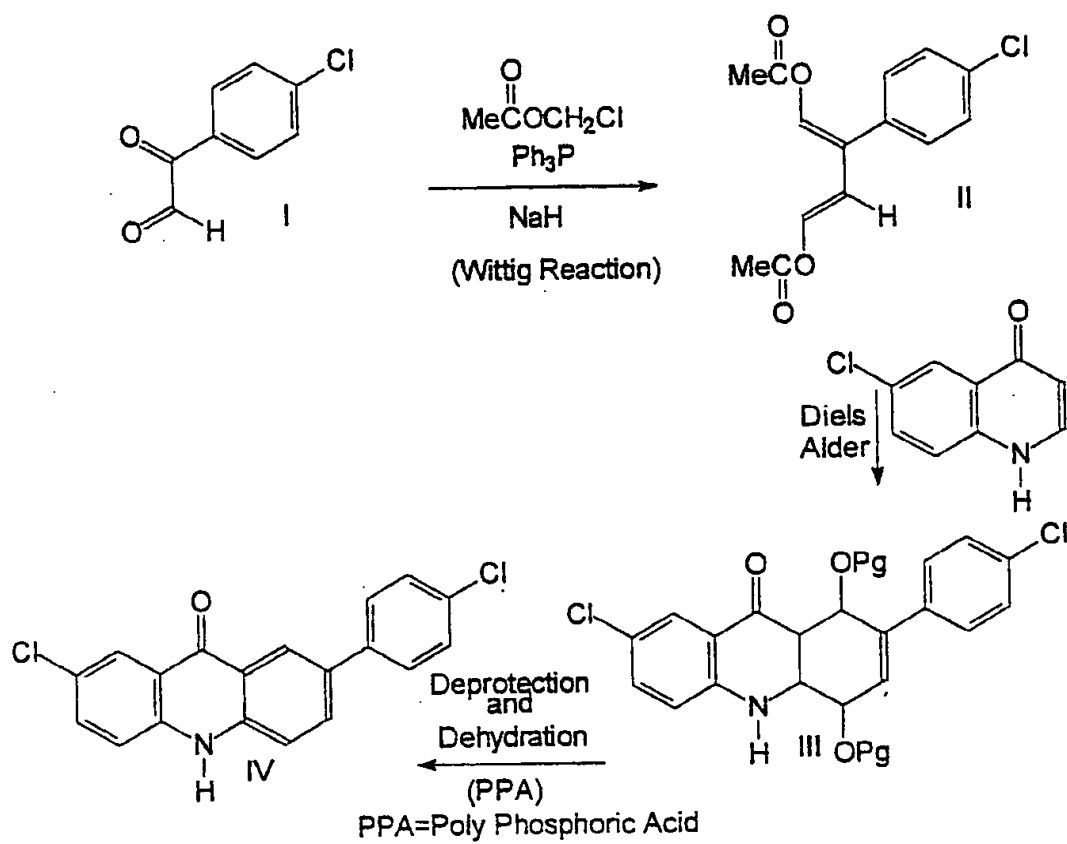


Fig. 3

Scheme 2:

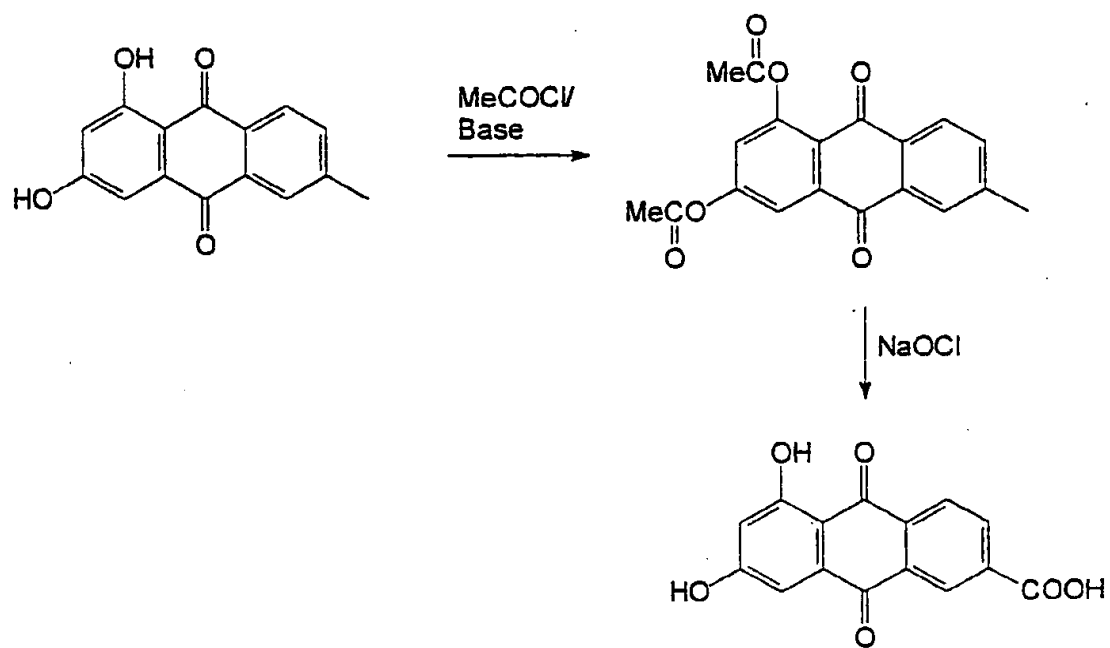


Fig. 4

Scheme 3:

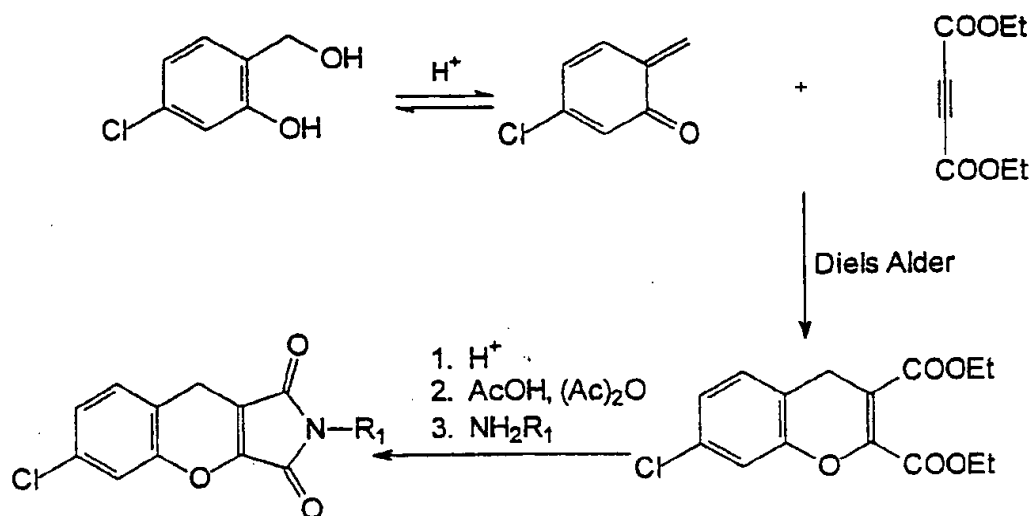


Fig. 5

INTERNATIONAL SEARCH REPORT

Int. l. Application No

PCT/CA 00/00541

A. CLASSIFICATION OF SUBJECT MATTER

IPC 7 C07D221/14 A61K31/473 A61P25/28

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 7 C07D A61K A61P

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, WPI Data, PAJ, CHEM ABS Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	WO 98 17278 A (ALLELIX BIOPHARMA ;CHEN XIANNONG (CA); TEHIM ASHOK (CA)) 30 April 1998 (1998-04-30) claims	1-10
A	EP 0 206 322 A (I P A INTERNATIONAL PHARMACEUT) 30 December 1986 (1986-12-30) claims	3,10
A	US 3 821 383 A (SESTANJ K ET AL) 28 June 1974 (1974-06-28) claims	3,10
A	FR 2 521 139 A (KI I ENDOKRINOLOGII) 12 August 1983 (1983-08-12) claims	3,10
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☒ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

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"&" document member of the same patent family

Date of the actual completion of the international search

18 September 2000

Date of mailing of the international search report

25/09/2000

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INTERNATIONAL SEARCH REPORT

In. ational Application No

PCT/CA 00/00541

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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Information on patent family members

International Application No

PCT/CA 00/00541

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